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DIFFRACTION BY A PERFECTLY CONDUCTING RECTANGULAR CYLINDER WHICH IS ILLUMINATED BY AN ARRAY OF LINE SOURCES

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16. Abstract

The geometrical theory of diffraction (GTD) is employed to analyze the radiation from a perfectly-conducting rectangular cylinder illuminated by an array of line sources. The excitation of the cylinder by a single electric or magnetic current line source is considered first, and a solution which includes contributions from the geometrical optics rays and all singly- and doubly-diffracted rays is obtained. A new diffraction coefficient valid in the transition regions of the shadow and reflection boundaries is employed to obtain a continuous total field, except for negligible discontinuities in the doubly-diffracted field at its shadow boundaries. Patterns calculated by the GTD method are found to be in excellent agreement with those calculated from an integral equation formulation. Using superposition the solution for array or aperture excitation of the rectangular cylinder is obtained. A computer program for this solution is included.

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I. INTRODUCTION

In this report the geometrical theory of diffraction (GTD) [1] is used to treat the diffraction by a perfectly-conducting rectangular cylinder which is illuminated by an array of electric or magnetic current line sources. The illumination by a single line source of the array is considered first with the geometry of the problem shown in Fig. 1. The scattered and total fields are calculated at all points exterior to the rectangular cylinder, except for the shaded regions around the source and edges, which are excluded because of the nature of the high-frequency approximation. More will be said about this later. The solution is then generalized to calculate the field of linear arrays of such line sources radiating in the presence of the cylinder.

The scattering by a rectangular cylinder has been considered previously for the special case of plane wave incidence. Mei and VanBladel [2,3] formulated the problem in terms of an integral equation which they solved numerically to find the surface currents on the rectangular cylinder. They give radiation patterns, scattering cross sections, and surface currents for both E- and H-polarized incident waves. There are two disadvantages associated with this method: 1) as the frequency increases, difficulties are encountered with the convergence of the solution (this is particularly true when the technique is employed to solve a three-dimensional scattering problem), 2) the solution provides no physical insight into the scattering mechanism. Morse [4] also studied this problem using the ordinary GTD to obtain expressions for the diffracted field away from shadow and reflection boundaries. Since the ordinary theory fails at shadow and reflection boundaries, he introduced supplementary solutions there. He employed Oberhettinger's uniform asymptotic solution [5] near the boundaries of the incident and reflected fields, and he employed an integral representation of the field near the shadow boundaries of the fields of the diffracted rays. Thus, he did not obtain a compact high-frequency solution to this problem. The difficulties encountered by Morse at these boundaries may be overcome with a new edge diffraction coefficient derived by Kouyoumjian and Pathak [6,7]. This diffraction coefficient can be applied in the transition regions adjacent to the shadow and reflection boundaries so that one obtains a total field which is valid and continuous everywhere away from edges and caustics. Their diffraction coefficient is employed in this analysis.

Using Keller's Generalized Fermat's Principle, we include contributions to the total field from the geometrical optics fields (incident and reflected), as well as singly-diffracted fields which appear to emanate from the edges. Doubly-diffracted fields have also been included to describe the interactions between the edges; however, multiply-diffracted rays of higher order have been neglected because, in general, their fields contribute insignificantly, for the problem defined here. The incident, reflected and diffracted rays may be shadowed in the geometrical optics sense, and hence they contribute to the total field only in their respective regions of illumination. Discontinuities in the

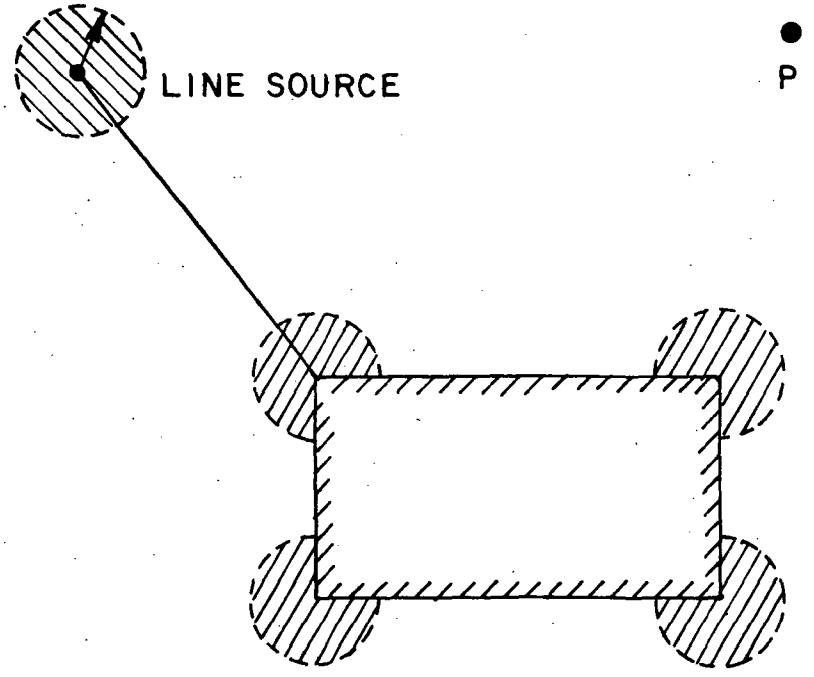

Fig. 1. Line source in the presence of the rectangular cylinder.

field are introduced at shadow boundaries and at the reflection boundaries, but they are symstematically removed by employing the new diffraction coefficient for the edge diffracted field mentioned previously. It should be pointed out that there are some residual discontinuities due to uncompensated discontinuities in the field of the doubly-diffracted rays at their shadow boundaries. However, these discontinuities are so small that they are not apparent in the plotted patterns. The patterns calculated from our GTD solution are found to be in excellent agreement with those calculated from numerical solutions.

Due to the high-frequency approximations of the incident and diffracted fields, our solution is restricted so that the following distances are greater than 0.7 wavelength.

1) The distance between the line source and the closest edge of the rectangular cylinder,

2) the distance between the observation point P and the closest edge of the rectangular cylinder,

3) the distances between the edges of the rectangular cylinder,

4) the distance between the observation point P and the closest line source, when calculating the incident or total fields.

A computer program based on the GTD solution for the rectangular cylinder in the presence of an array source has been written and is included in the report. With this program, it is possible to obtain numerical results for both the near- and far-fields of the cylinder under quite general conditions of illumination. Thus, the program is directly relevant to both antenna and scattering problems. As an example of its versatility, one notes that the program may be used to compute the pattern of an array of magnetic line sources mounted directly on the rectangular cylinder, provided the sources are not too close to an edge.

II. METHOD OF SOLUTION

Keller's geometrical theory of diffraction [1] is an extension of geometrical optics in which diffracted rays are introduced by a generalization of Fermat's principle, the excitation of the diffracted field is treated as a local phenomenon, and away from the diffracting surface the behavior of the diffracted field along its ray is the same as that of the geometrical optics field. The basic idea of GTD is that the field of the line source illuminates the rectangular cylinder giving rise to a reflected field and an edge diffracted field, which consists of the fields of singly and multiply-diffracted rays. The total field U(P) at a point P is equal to the sum of the fields on all rays through P.

$$(1) \qquad U(P) = \sum_{\text{rays}} U_i(P)$$

which includes the incident field if P is not in the shadow region. The wave function U(P) represents a magnetic field parallel to the edge in case of a magnetic line source, and an electric field parallel to the edge in the case of an electric current line source. The pertinent rays and their associated fields will be discussed briefly in the following paragraphs.

A. Geometrical Optics Rays - Direct and Reflected

Let us consider the field radiated from a line source at O and observed at P as shown in Fig. 2. Fermat's principle predicts only the direct ray OP. If a line source is being considered, the field along OP is given by

$$(2) \qquad U^i(P) = C \frac{e^{-jks_o}}{\sqrt{s_o}} \quad ,$$

where s_o is the distance between O and P, and C is a conveniently chosen normalization constant. For the configuration shown in Fig. 2, the space surrounding the right-angle wedge may be divided into three regions:

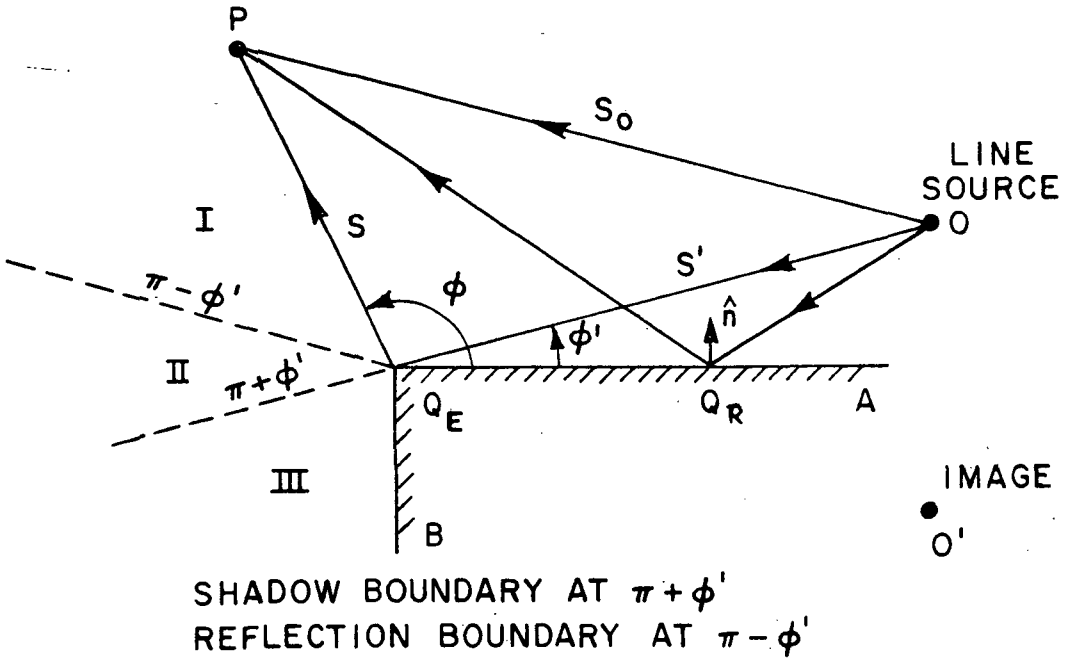

Fig. 2. Line source in the presence of a wedge.

Region I	$0 \leq \phi < \pi - \phi'$,
Region II	$\pi - \phi' < \phi < \pi + \phi'$,
Region III	$\pi + \phi' < \phi < 3\pi/2$.

Region III is the shadow region, which is not penetrated by the incident ray; the incident field vanishes here.

We know that there is a field reflected from the surface AQ_E. To describe this we introduce an additional class of rays which include on their trajectory a point Q_R of the surface AQ_E. Applying Fermat's principle, the distance OQ_RP along the ray path is a minimum and the law of reflection results. This simple extension of Fermat's principle which accounts for the reflected ray is so natural that we accept it without question. The field of the reflected ray is readily deduced from image theory as

$$(3) \qquad U^r(P) \equiv U^r(A\text{-}Q_E) = \pm C \frac{e^{-jks''}}{\sqrt{s''}} \quad ,$$

where the positive sign is for Neumann (hard) boundary condition associated with the magnetic current line source, the negative sign is for the Dirichlet (soft) boundary condition associated with the electric current source line, and s" is the distance between the image O' and the observation point P. The reflected field vanishes in regions II and III, which the reflected ray does not penetrate. Let us consider now a further extension of Fermat's principle.

B. Singly-Diffracted Rays

It is well known that the ray incident on the edge Q_E in Fig. 2 gives rise to diffraction. To account for this, Keller introduced a class of rays which includes the point Q_E in its trajectory. This completely determines the diffracted ray path in the isotropic, homogeneous medium of this two-dimensional problem, so the law of edge diffraction becomes trivial under these circumstances.

In terms of GTD, the diffracted field at P for the line source at O is

$$U^d(Q_E) = U^i(Q_E)\, D_{\substack{s\\h}}(\phi,\phi')\, \frac{e^{-jks}}{\sqrt{s}} \quad , \tag{4}$$

where D_s is the scalar diffraction coefficient for the accoustically soft (Dirichlet) boundary condition and D_h is the scalar diffraction coefficient for the accoustically hard (Neumann) boundary condition. They are deduced from the general dyadic diffraction coefficient $\bar{\bar{D}}(\phi,\phi',\beta_0)$ obtained by Kouyoumjian and Pathak [6,7]. For the special case where the incident ray is perpendicular to a straight edge, the scalar diffraction coefficients are given by

$$D_{\substack{s\\h}}(\phi,\phi') = \frac{-e^{-j\,\pi/4}}{2n\sqrt{2\pi k}} \left\{ \left[\cot\left(\frac{\pi+(\phi-\phi')}{2n}\right) F[kLa^+(\phi-\phi')] + \cot\left(\frac{\pi-(\phi-\phi')}{2n}\right) F[kLa^-(\phi-\phi')] \right] \right. \tag{5}$$

$$\left. \pm \left[\cot\left(\frac{\pi+(\phi+\phi')}{2n}\right) F[kLa^+(\phi+\phi')] + \cot\left(\frac{\pi-(\phi+\phi')}{2n}\right) F[kLa^-(\phi+\phi')] \right] \right\}$$

where $n\pi$ is the exterior wedge angle, which equals $3\pi/2$ in this case, and

$$F(x) = 2j|\sqrt{X}|\, e^{jX} \int_{|\sqrt{X}|}^{\infty} e^{-j\tau^2}\, d\tau \tag{6}$$

in which

$$a^{\pm}(\phi\pm\phi') = 2\cos^2\left(\frac{2n\pi N^{\pm} - (\phi\pm\phi')}{2}\right) . \tag{7}$$

$N^{\pm}$ are the integers which most nearly satisfy the following equations

$$2\pi n N^{+} = \pi + (\phi \pm \phi') \tag{8}$$

$$2\pi n N^{-} = -\pi + (\phi \pm \phi') \tag{9}$$

and kL is the large parameter in the asymptotic evaluation of the pertinent integrals involved in the derivation of the dyadic diffraction coefficient. The quantity L may be viewed as a distance parameter which depends upon the type of edge illumination; for line source illumination, L is given by

$$L = \frac{s\, s'}{s + s'} \tag{10}$$

For grazing incidence $\phi' = 0, n\pi$, D_h is multiplied by a factor of $\frac{1}{2}$; furthermore, if the diffracted ray grazes the surface in the case of a soft boundary, $D_s = 0$ and the diffracted field vanishes, as it should.

The field of the singly-diffracted ray is discontinuous at the shadow and reflection boundaries in a way which compensates the discontinuities in the geometrical optics fields there. This is readily demonstrated; consider for example the incident and diffracted fields at the shadow boundary, where to simplify the discussion, it is assumed there is no nearby reflection boundary. Let $\pi+\phi'-\varepsilon$ be a point close to the shadow boundary, see Fig. 2. In the illuminated region $\varepsilon > 0$ and in the shadow region $\varepsilon < 0$.

$$U(\phi) = \begin{cases} C\,\dfrac{e^{-jks_0}}{\sqrt{s_0}} + C\,\dfrac{e^{-jks'}}{\sqrt{s'}}\, D_{s,h}(\phi'+\pi-\varepsilon,\phi')\,\dfrac{e^{-jks}}{\sqrt{s}}\,, & \varepsilon > 0 \\ C\,\dfrac{e^{-jks'}}{\sqrt{s'}}\, D_{s,h}(\phi'+\pi-\varepsilon,\phi')\,\dfrac{e^{-jks}}{\sqrt{s}}\,, & \varepsilon < 0 \end{cases} \tag{11}$$

For ε small it follows from Eq. (5), that

$$D_{s,h}(\phi'+\pi-\varepsilon,\phi') = \frac{-e^{-j\,\pi/4}}{2n\sqrt{2\pi k}} \left\{ \cot\frac{\varepsilon}{2n}\; F\left[kLa^{-}(\pi-\varepsilon)\right] \right. \tag{12}$$

$$\left. + \text{smaller terms which are continuous at the shadow boundary} \right\} .$$

From Eq. (9),

$$N^- = 0$$

Also, as $\varepsilon \to 0$,

$$\cot\left(\frac{\varepsilon}{2n}\right) = \frac{2n}{\varepsilon} \tag{13}$$

$$a^-(\pi-\varepsilon) = \frac{\varepsilon^2}{2} \tag{14}$$

$$F[kLa^-(\pi-\varepsilon)] = \sqrt{\pi kL/2}\, e^{j\pi/4} \quad |\varepsilon| \tag{15}$$

Substituting Eqs. (13) and (15) into Eq. (12) as $\varepsilon \to 0$,

$$D_{s_h}(\phi'+\pi-\varepsilon,\phi') = -\tfrac{1}{2}\sqrt{\frac{s'\,s}{s+s'}} \quad \operatorname{sgn}\varepsilon + \text{smaller, continuous terms,} \tag{16}$$

$$s_0 = s' + s \quad . \tag{17}$$

Upon substituting Eqs. (16) and (17) into Eq. (11), it is seen that the total field is continuous at the shadow boundary. In an analogous manner it can be shown that the total field is continuous at the reflection boundary.

C. Doubly-Diffracted Rays

When one face of the conducting wedge is terminated at Q_F as shown in Fig. 3, a second order diffracted-ray will emanate from the edge Q_F. In terms of the GTD, the doubly-diffracted field at P due to the line source at O can be written as

$$U^d(Q_E,Q_F) = U^i(Q_F)\ \tfrac{1}{2}\ D_{s_h}(\phi_2,0)\ \frac{e^{-jks}}{\sqrt{s}} \tag{18}$$

$$= \left\{U^i(Q_E)\ D_{s_h}\left(\frac{3\pi}{2},\phi'\right)\ \frac{e^{-jkh}}{\sqrt{h}}\right\}\ \frac{D_{s_h}(\phi_2,0)}{2}\ \frac{e^{-jks}}{\sqrt{s}} \quad .$$

Since $D_s(3\pi/2,\phi') = 0$, the contribution from the doubly-diffracted rays vanishes for the soft boundary according to the above expression. If a higher order approximation for the doubly-diffracted field is employed, then this contribution is non-vanishing, as will be explained later.

The field of the ray singly-diffracted at Q_E has a shadow boundary $SB(Q_E)$ as shown in Fig. 3; the singly-diffracted ray does not penetrate

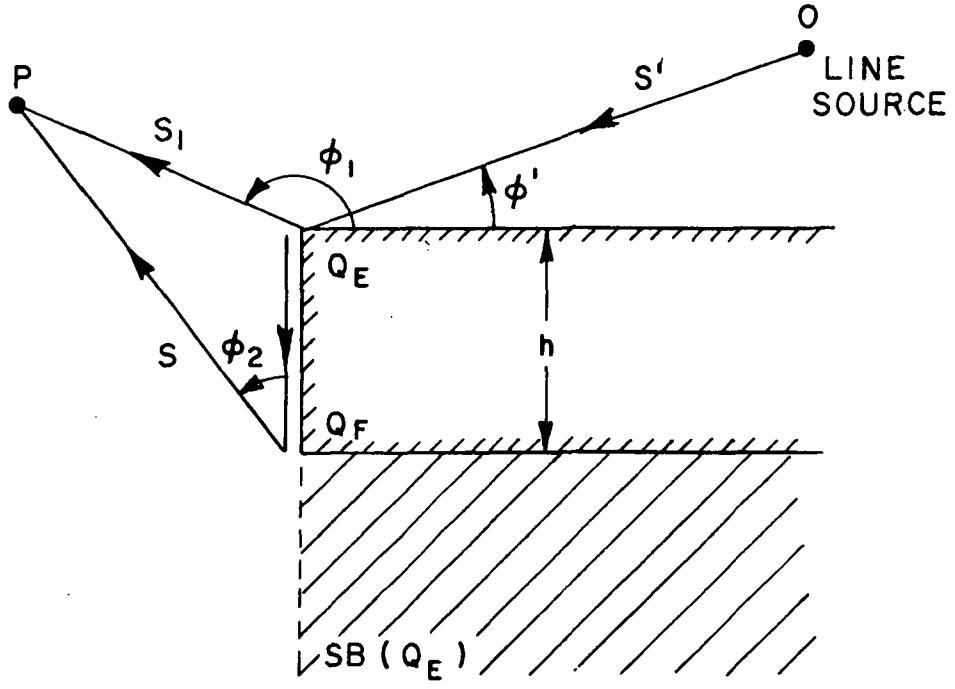

Fig. 3. Configuration for double-diffraction.

the shaded region. It will be shown next that the discontinuity in the field of the singly-diffracted ray at $SB(Q_E)$ is compensated by the ray doubly-diffracted from Q_F, so that the total diffracted field is continuous at this boundary. Since the field doubly diffracted vanishes in the case of the soft boundary, we only need to treat the hard boundary here.

Consider a point close to $SB(Q_E)$ so that $\phi_2 = \pi-\varepsilon$, the total diffracted field at this boundary is

$$(19) \qquad U^{TD} = \begin{cases} U^i(Q_E)\, D_h(\phi_1,\phi')\, \dfrac{e^{-jks_1}}{\sqrt{s_1}} + U^i(Q_F)\, \dfrac{D_h(\pi-\varepsilon,0)}{2}\, \dfrac{e^{-jks}}{\sqrt{s}}, & \varepsilon > 0 \\ U^i(Q_F)\, \dfrac{D_h(\pi-\varepsilon,0)}{2}\, \dfrac{e^{-jks}}{\sqrt{s}}, & \varepsilon < 0 \end{cases}$$

where s_1, ϕ_1 are the coordinates of the ray diffracted from Q_E, and

$$(20) \qquad U^i(Q_F) = U^i(Q_E) D_h\left(\frac{3\pi}{2}, \phi'\right) \frac{e^{-jkh}}{\sqrt{h}} \quad .$$

When $\phi_2' = 0$ and the singly-diffracted ray grazes the vertical surface, the second and fourth terms in the expression for the diffraction coefficient are the same, except for the $\pm$ sign of the latter. This is also true for the first and third terms. As a result,

$$(21) \qquad D_h(\pi-\varepsilon,0) = \frac{-e^{-j\,\pi/4}}{n\sqrt{2\pi k}} \left\{ \cot\left(\frac{\varepsilon}{2n}\right) F[kLa^-(\pi-\varepsilon)] \right.$$

$$\left. + \text{smaller terms which are continuous at } SB(Q_E) \right\} \quad .$$

As $\varepsilon \to 0$, it is seen from Eqs. (12), (13), (14) and (15) that

$$(22) \qquad D_h(\pi-\varepsilon,0) = -\sqrt{\frac{hs}{s+h}} \quad \operatorname{sgn} \varepsilon;$$

furthermore,

$$(23) \qquad s_1 = h + s \quad .$$

Substituting Eqs. (22) and (23) into Eq. (19) and making use of Eq. (20), it is seen that the total diffracted field is continuous at the boundary $SB(Q_E)$.

As we have already noted, in the case of a soft boundary the field of an incident-ray grazing the surface vanishes, the edge-diffracted field is then proportional to the normal derivative of the incident field at the edge. The proportionality factor is a diffraction coefficient D' given by Karp and Keller [8]. Thus, for the case of Dirichlet problem, the doubly-diffracted field must be replaced by

$$(24) \qquad U^d(Q_E,Q_F) = \frac{\partial U^i(Q_F)}{\partial n} \frac{D'(\phi_2,0)}{2} \frac{e^{-jks}}{\sqrt{s}}$$

where

$$(25) \qquad D'(\phi_2,0) = \frac{1}{jk} \frac{\partial}{\partial \phi'} D_s(\phi_2,0)$$

The derivate $\partial U(Q_F)/\partial n$ is taken with respect to the normal to the surface $Q_E Q_F$. This contribution is weak in comparison with that of the singly-diffracted rays; the contribution of the former is of order $(1/k^2)$, whereas that of the latter is of order $(1/\sqrt{k})$. In calculating the field diffracted from the soft cylinder, it was found that the field of the doubly-diffracted rays did not contribute significantly, so the contribution from these rays can be omitted in this case.

Let us now turn to the diffraction by a rectangular cylinder illuminated by a line source. Depending on the location of the line source, the whole domain surrounded by the cylinder will be divided into regions by the various shadow boundaries and the reflection boundaries. Each of these boundaries is labeled to indicate how it originates. For example, referring to Fig. 4, the notation SB means the shadow boundary of the incident geometrical optics field $U^i(P)$, RB(A-B) is the shadow boundary of the geometrical optics field $U^r(A\text{-}B)$ reflected from the surface A-B, SB(A) is the shadow boundary of the singly-diffracted $U^d(A)$, which emanates from the edge A, and SB(A,B) is the shadow boundary of the doubly-diffracted field $U^d(A,B)$ which emanates from the edge B. The shadow boundary of the reflected field is referred to simply as the reflection boundary.

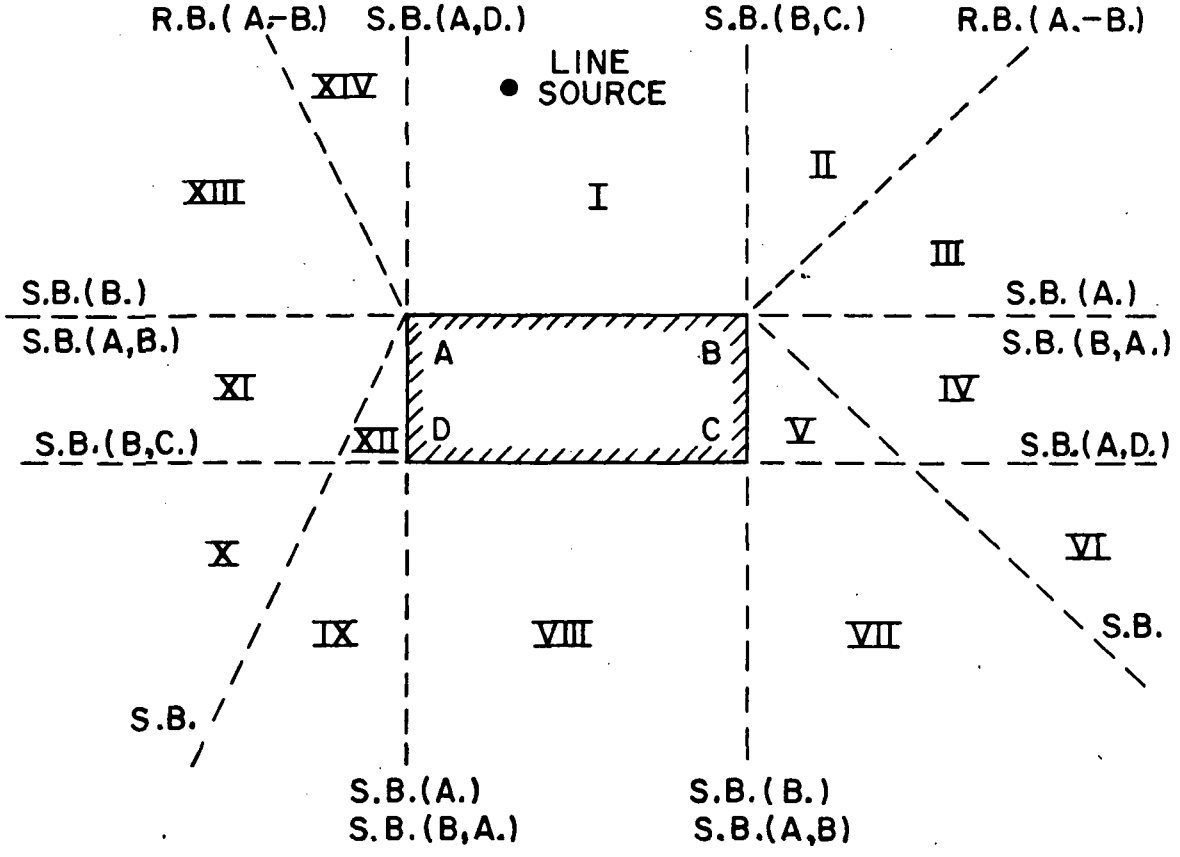

Fig. 4. Shadow and reflection boundaries of the GTD fields.

REGION / FIELD	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
μ^i	✓	✓	✓	✓		✓				✓	✓		✓	✓
$\mu^r(A-B)$	✓	✓												✓
$\mu^d(A)$	✓	✓	✓						✓	✓	✓	✓	✓	✓
$\mu^d(B)$	✓	✓	✓	✓	✓	✓	✓						✓	✓
$\mu^d(A,B)$	✓	✓	✓	✓	✓	✓	✓						✓	✓
$\mu^d(B,A)$	✓	✓	✓						✓	✓	✓	✓	✓	✓
$\mu^d(A,D)$						✓	✓	✓	✓	✓	✓	✓	✓	✓
$\mu^d(B,C)$		✓	✓	✓	✓	✓	✓	✓	✓	✓				

A CHECK (✓) MEANS THE FIELD IS NON-VANISHING IN THE REGION

TABLE I

In what follows we may locate the line source in the upper left hand quadrant of the space surrounding the cylinder, without loss of generality. Three cases will be considered.

1) First, the line source is located directly above the cylinder. The whole domain around the cylinder is divided into 14 regions as shown in Fig. 4. Table I shows the regions covered by each type of ray. To demonstrate the use of the table, let us consider an observation point P in region IX. Examining the column under region IX of Table I, one finds checks(✓) for $U^d(A)$, $U^d(B,A)$, $U^d(A,D)$, and $U^d(B,C)$. Thus the total field at P is equal to $U^T(P) = U^d(A) + U^d(B,A) + U^d(A,D) + U^d(B,C)$.

2) The line source is located to the upper left of the cylinder as shown in Fig. 5. In this case there are 18 regions. Table II shows the regions where a particular ray exists and its field makes a non-vanishing contribution.

3) Line source at grazing incidence. Let the line source be located in the plane which contains the A-D side of the rectangular cylinder as shown in Fig. 6. This case is of special interest because the trailing edge D lies in the shadow of the leading edge A. Also, it lies on the shadow boundary of the direct geometrical optics field. The behavior of the field at the boundary DP must be treated separately, see Appendix I. As before, the domain surrounding the cylinder is divided into regions as shown in Fig. 6 and Table III gives the regions covered by the individual rays.

Recall that one or more of the various field components is discontinuous at each boundary shown in Figs. 4, 5 and 6 but that all except the discontinuities in the doubly diffracted fields are compensated; e.g., the discontinuities in the geometrical optics field are compensated by the field of the singly-diffracted rays and the discontinuities in the field of the singly-diffracted rays are compensated by the fields of the doubly-diffracted rays.

As a final step in the anslysis, the fields of the individual line sources are superimposed to give the field of a linear array of line sources radiating in the presence of the cylinder, see Fig. 7. A computer program has been written to calculate the incident, total and scattered fields once the linear array is specified. Unlike its earlier definition for geometrical optics, the term incident field used here means the field of the array in the absence of the cylinder, and the scattered field is simply the difference between the total field and this incident field. The versatility of such a program is evident; the scattering from the cylinder for a wide variety of illuminations can be studied, and the radiation from antennas in the presence of the rectangular cylinder also can be studied. As a matter of fact, the program

was written originally so that the linear array of line sources, when densely packed, closely approximates the field of an aperture antenna of finite width W. The aperture antenna (more precisely its axis) is directed toward a point Q on the surface of the rectangular cylinder as shown in Fig. 7. A description of the aperture radiation in terms of an array of discrete line sources is discussed in the following paragraphs.

The aperture distribution may be approximated by a discrete array of line sources which are properly weighted in amplitude and phase. The width of the aperture denoted by W, is divided into 2M segments; (M = integer). The line sources are positioned at the ends of these segments, which introduces 2M + 1 line sources. In approximating a continuous distribution, the number M is selected so that $2M + 1 \geq 10\ W/\lambda$, where λ = free space radiated wavelength.

Three types of line sources are available in this program:

Type I	An electric current line source
Type II	A magnetic current line source
Type III	A magnetic current moment line source.

As described earlier, the electric current line source radiates an omnidirectional electric field which is parallel to the edge of the rectangular cylinder, and the magnetic current line source radiates an omnidirectional magnetic field which is parallel to the edge of the rectangular cylinder. The magnetic current moment line source consists of a continuous array of magnetic current moments directed perpendicular to the line of the array and parallel to the aperture in question. This line source radiates an electric field parallel to the edge of the cylinder; however, the field has a pattern, $|\cos\theta|$, where θ is shown in Fig. 7. The strength of these magnetic type line sources is determined from the equivalent magnetic surface currents in the aperture. $\overline{K_S} = \overline{E} \times \hat{n}$, where $\overline{E}$ is the electric field distribution in the aperture (assumed known) and $\hat{n}$ is the outward normal to the aperture.

The field of the two-dimensional aperture can be adequately represented in the forward direction by a densely-packed array of type II and type III line sources, but such an array fails to approximate the field adequately at aspects behind the aperture. This limitation is particularly troublesome when calculating the total field. To overcome this difficulty an obliquity factor has been included in the program which multiplies the pattern of each line source. The obliquity factor is $f(\theta) = \cos^n \theta/2$, where $n = 0, \frac{1}{2}, 1, 2$. When $n = 0$, the obliquity factor is unity so that the array radiates symmetrically with respect to the axis of its elements. The case $n = 2$ occurs naturally in the description of the radiation fields of aperture antennas via the Kirchhoff-Huygen's approximation (for the forward region). The cases $n = \frac{1}{2}$, and $n = 1$ are added so that the n which best approximates the measured aperture pattern may be used. It is evident that the obliquity factor results in a pattern null in the direction directly behind the aperture at $\theta = \pi$. In most practical cases, there is no such null in the backward direction.

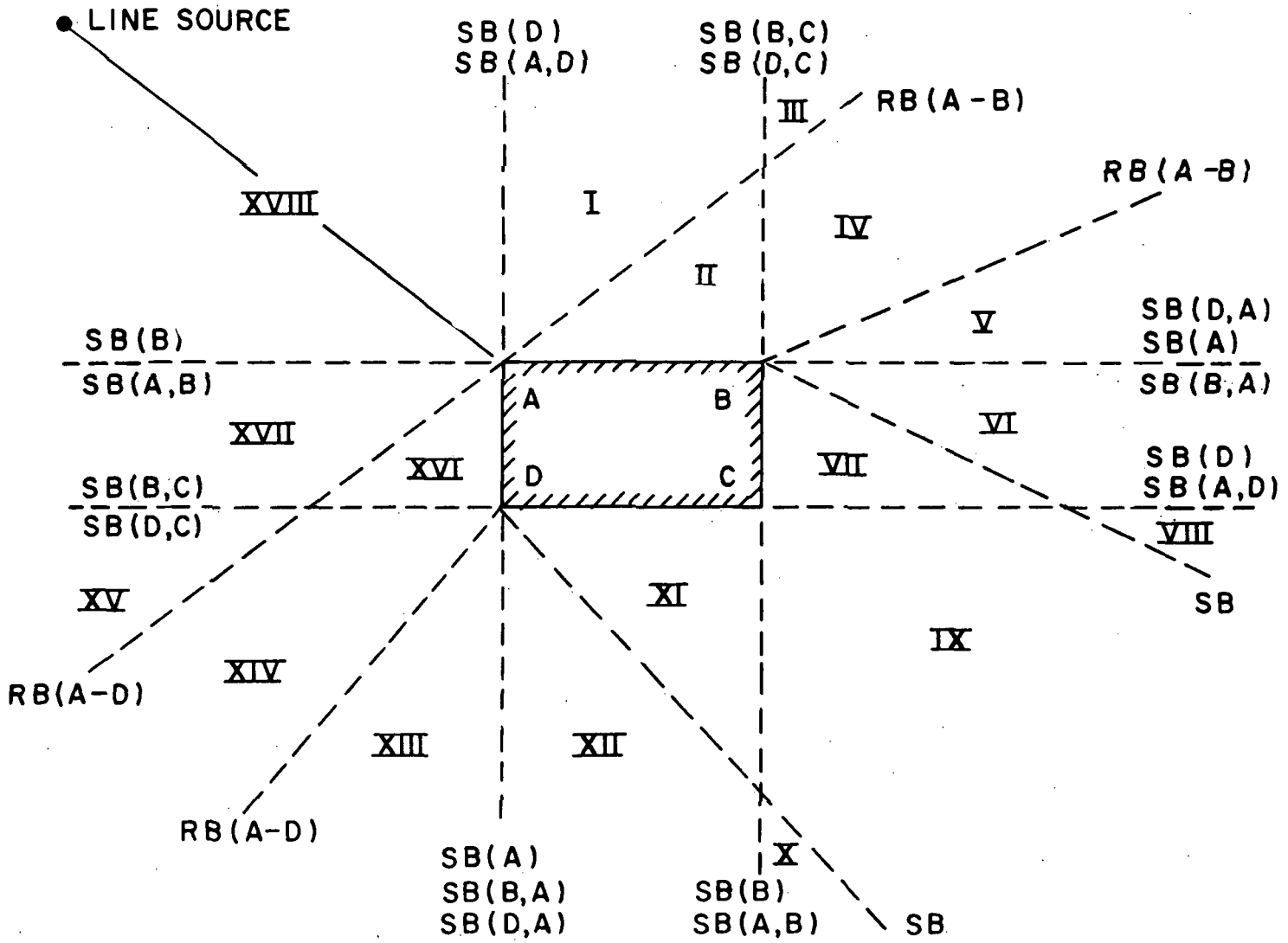

Fig. 5. Shadow and reflection boundaries of the GTD fields

FIELD \ REGION	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII
μ^i	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓
$\mu^r(A-B)$		✓		✓														
$\mu^r(A-D)$														✓		✓		
$\mu^d(A)$	✓	✓	✓	✓	✓								✓	✓	✓	✓	✓	✓
$\mu^d(B)$	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								✓
$\mu^d(D)$								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
$\mu^d(A,B)$	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								✓
$\mu^d(B,A)$	✓	✓	✓	✓	✓								✓	✓	✓	✓	✓	✓
$\mu^d(A,D)$								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
$\mu^d(D,A)$	✓	✓	✓	✓	✓								✓	✓	✓	✓	✓	✓
$\mu^d(B,C)$			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
$\mu^d(D,C)$			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			

TABLE II

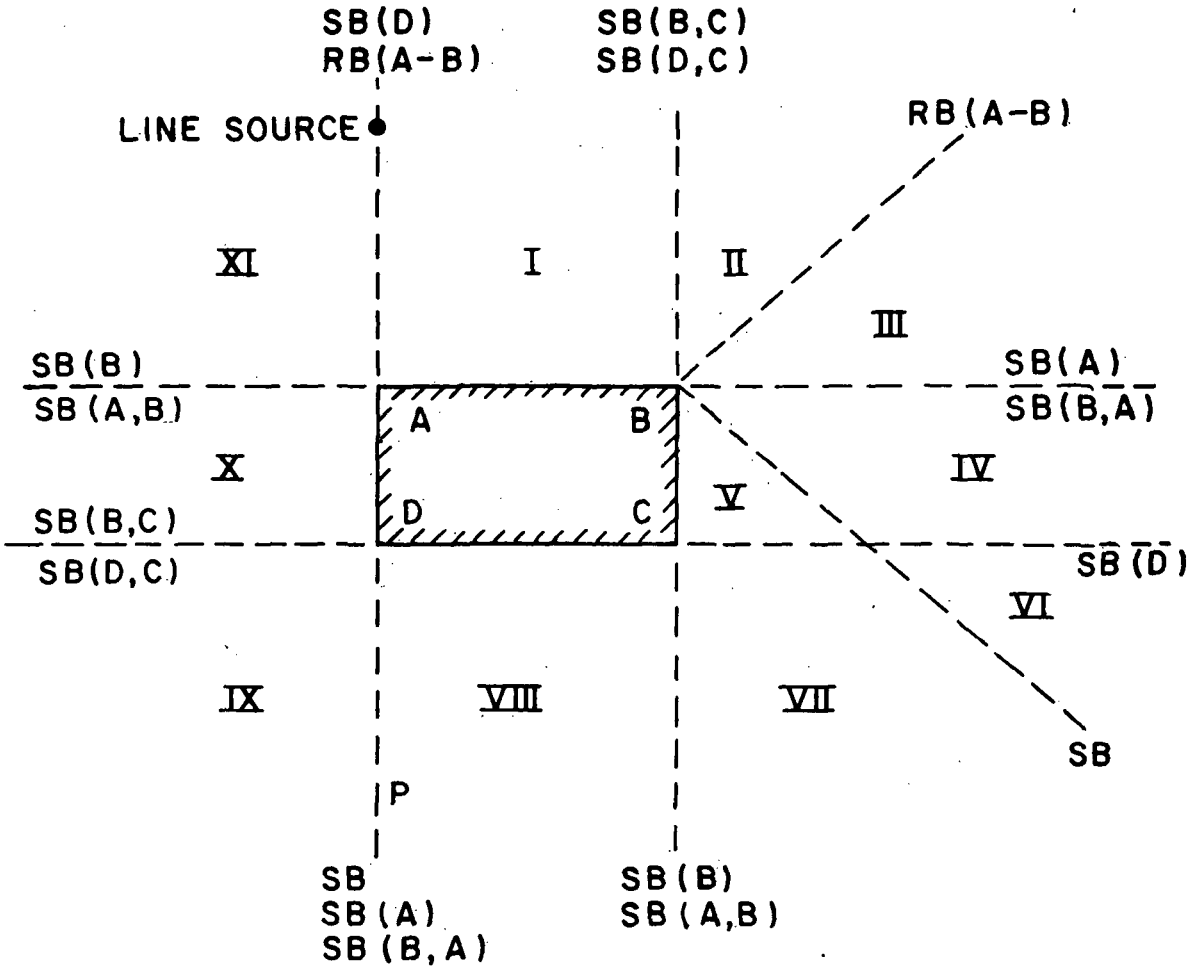

Fig. 6. Shadow and reflection boundaries of the GTD fields.

FIELD \ REGION	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
$\mu^i(p)$	✓	✓	✓	✓		✓			✓	✓	✓
$\mu^r(A-B)$	✓	✓									
$\mu^d(A)$	✓	✓	✓						✓	✓	✓
$\mu^d(B)$	✓	✓	✓	✓	✓	✓	✓				✓
* $\mu^d(D)$						✓	✓	✓	✓	✓	✓
$\mu^d(A,B)$	✓	✓	✓	✓	✓	✓	✓				✓
$\mu^d(B,A)$	✓	✓	✓						✓	✓	✓
$\mu^d(B,C)$		✓	✓	✓	✓	✓	✓	✓	✓		
$\mu^d(D,C)$		✓	✓	✓	✓	✓	✓	✓	✓		

* SEE APPENDIX I

TABLE III

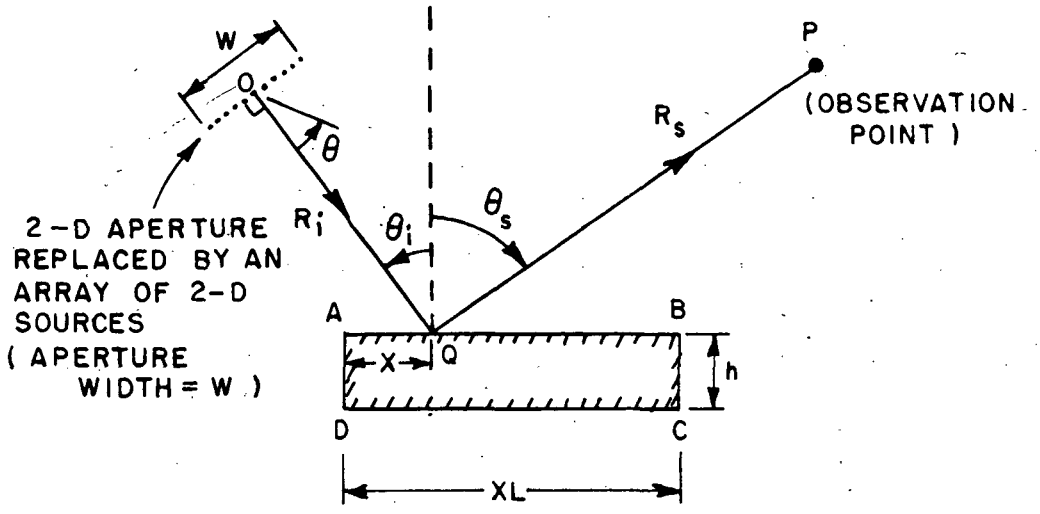

Fig. 7. An array of line source in the presence of the rectangular cylinder.

On the other hand, the pattern in the forward region is quite satisfactory when the obliquity factor is included, and as one moves away from the forward region, the pattern drops to a level where the differences between the simulated and measured patterns are unimportant when computing the total field surrounding the rectangular cylinder.

The scattered, and the total fields are computed as a function of $\theta_s(-\pi \leq \theta_s \leq \pi)$ at a range R_s. The incident field pattern on the other hand is available for a phase reference at the center of the array (aperture) at O in Fig. 7 and computed at a range measured from O, as well as for a phase reference at Q with a range R_s (just as for the scattered and the total fields).

The input and output variables for the computer program are described in Appendix II, and the listing of the computer program is given. Also, a sample case is treated in this appendix to illustrate the use of the program.

III. NUMERICAL RESULTS

To assess the accuracy of the GTD solution described in the preceding section, it was applied to several simple examples, where the rectangular cylinder is illuminated by either an electric or magnetic current line source. Far-zone patterns for the total field are calculated by this method and also from numerical solutions of the pertinent integral equation*. The cylinders are square with a side length of 1.6

*The computer programs for the integral equation solutions were provided by Prof. J.H. Richmond of the ElectroScience Laboratory.

wavelength, and in each case the line source illuminates the cylinder from a distance of 0.8 wavelength. These small distances provide a stringent test of our GTD solution; also they give us an opportunity to examine the accuracy of the new scalar diffraction coefficients in a situation where the edges are illuminated by curved wavefronts and where the transition regions are relatively broad. The pattern calculated from the integral equation solution must be considered more accurate for the small dimensions chosen for these examples, since the integral equation method is convergent whereas the GTD solution is an asymptotic approximation.

Patterns for magnetic current line source excitation (hard boundary case) are given in Figs. 8, 9 and 10, where the line source is positioned on the diagonal of the square cylinder, on the centerline directly above the cylinder, and at a point of glancing incidence on one of its surfaces. The agreement between the patterns calculated by the GTD and the integral equation method is remarkable - every detail is the same within the limits of graphical accuracy. The corresponding patterns for electric current line source excitation (soft boundary case) are presented in Figs. 11, 12 and 13. Again there is excellent agreement between the two pattern calculations, except in the vicinity region of forward scatter in Figs. 12 and 13. Note that the level of the patterns is very low in these regions, so that small errors in the solution become significant. We hope to look into the reason for these differences at a later time.

The numerical examples considered here confirm the accuracy and applicability of our GTD solution; this is further demonstrated by an example treated in Appendix II. As the size of the cylinder and the distance between the edges of the cylinder and the source (or sources) increases in terms of a wavelength, one can expect the accuracy of the GTD solution to increase, because it is an asymptotic approximation where $k = 2\pi/\lambda$ is a large parameter.

In the case of magnetic current line source excitation there is little evidence of shadowing in the forward direction by the small square cylinder; however, there is distinct evidence of shadowing in the case of electric current line source excitation, where the total electric field is parallel to the cylinder and must vanish at its surface. One should expect this.

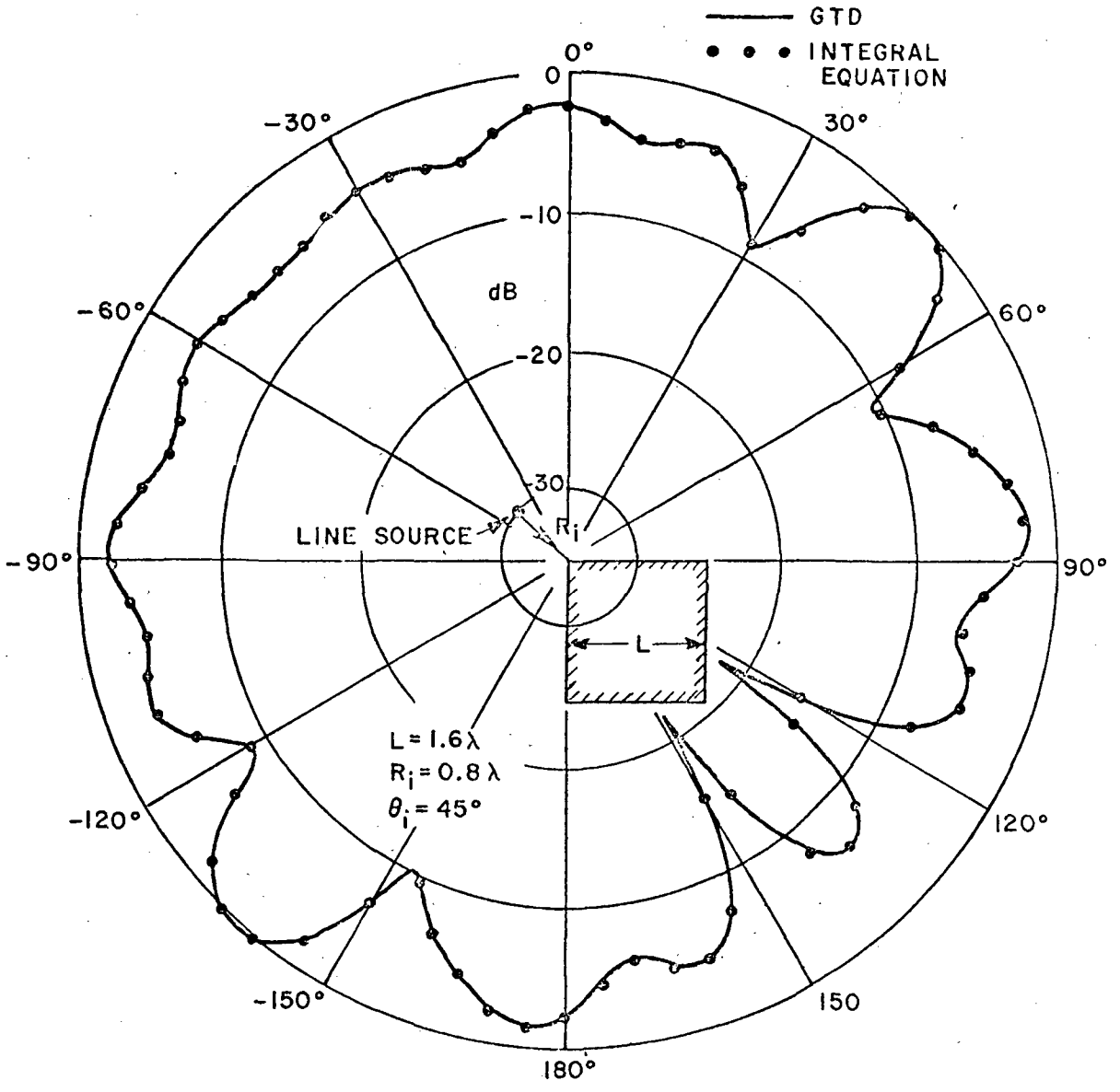

Fig. 8. Pattern of a magnetic current line source in the presence of a rectangular cylinder.

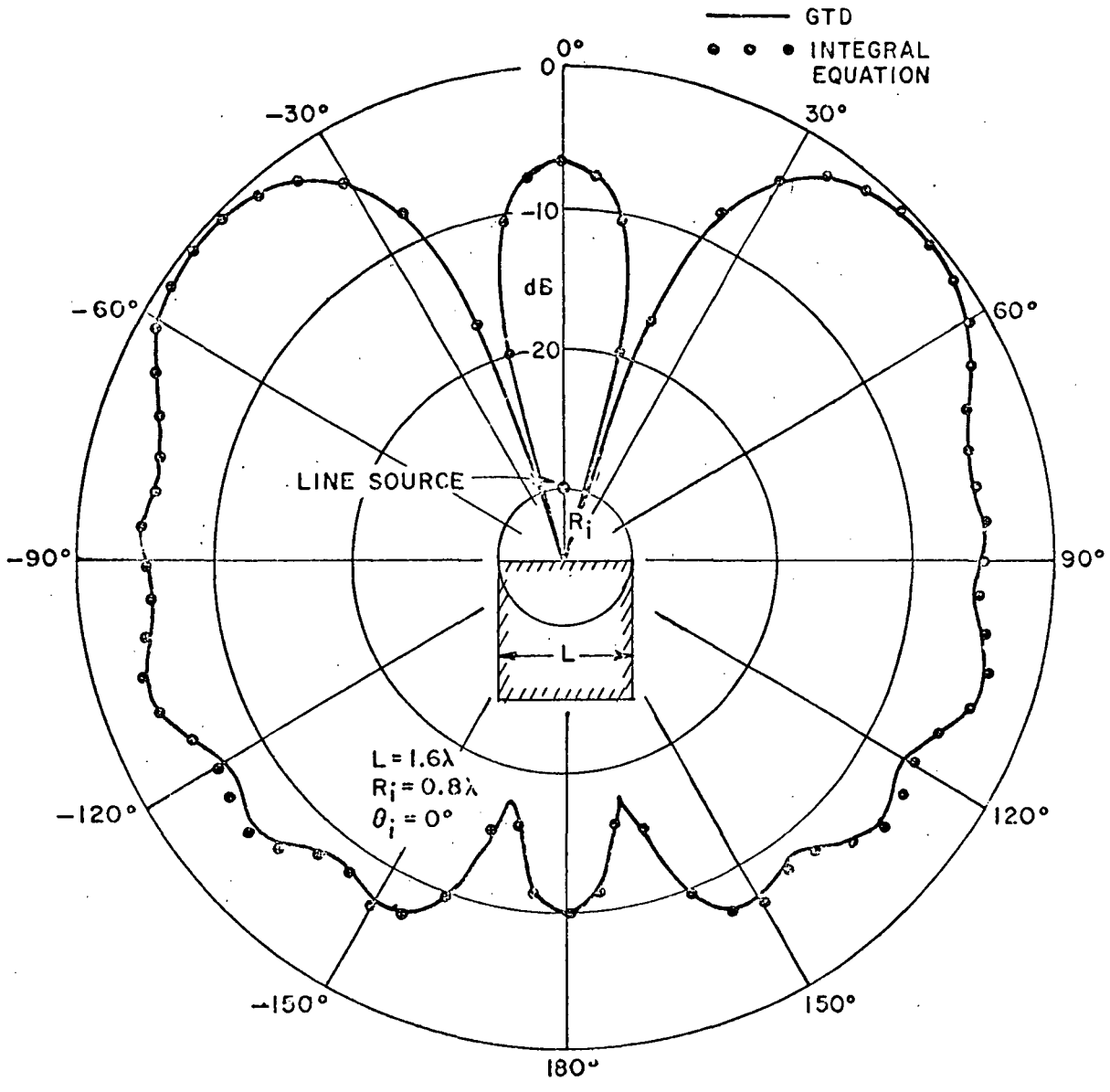

Fig. 9. Pattern of a magnetic current line source in the presence of a rectangular cylinder.

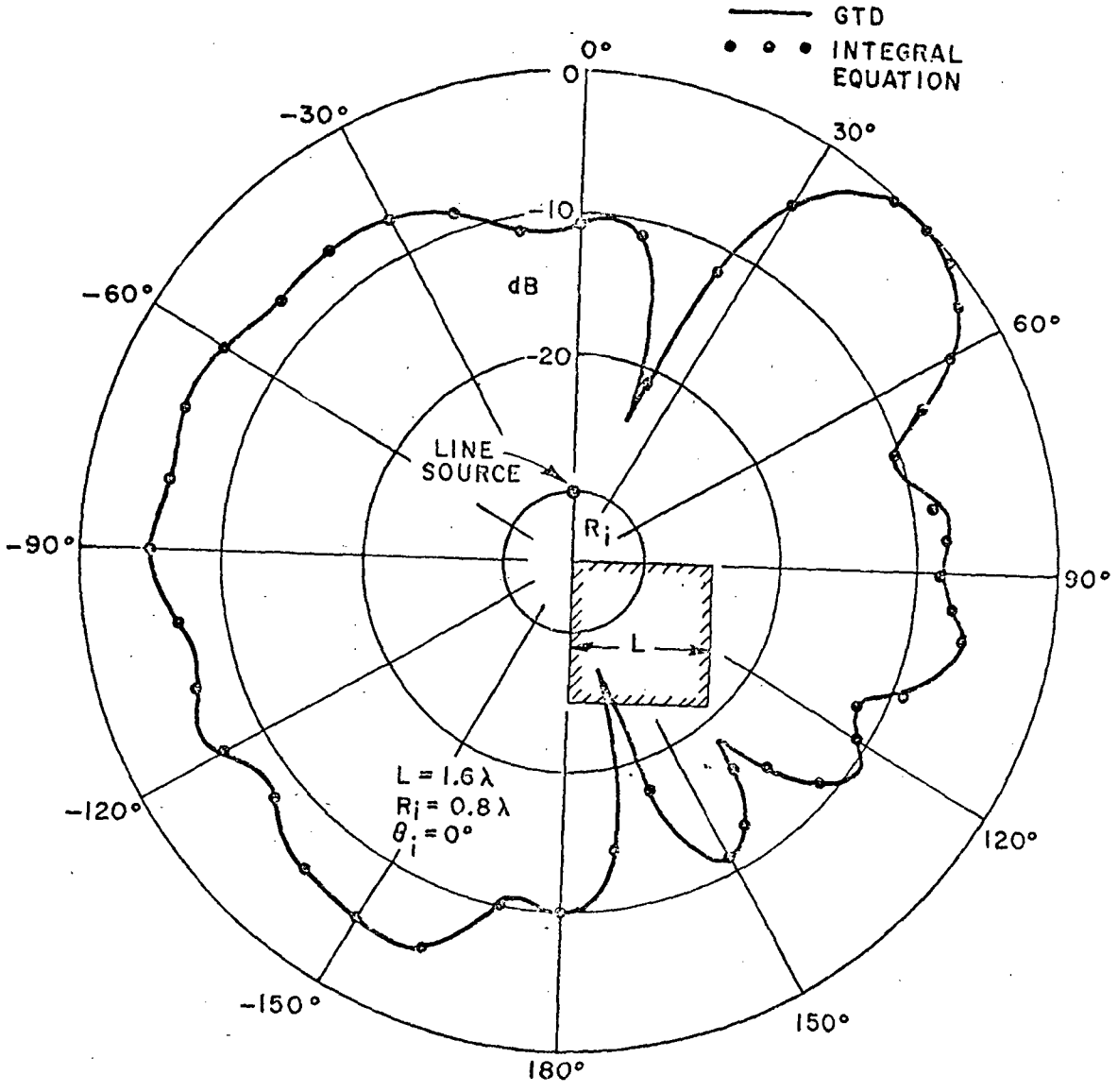

Fig. 10. Pattern of a magnetic current line source in the presence of a rectangular cylinder.

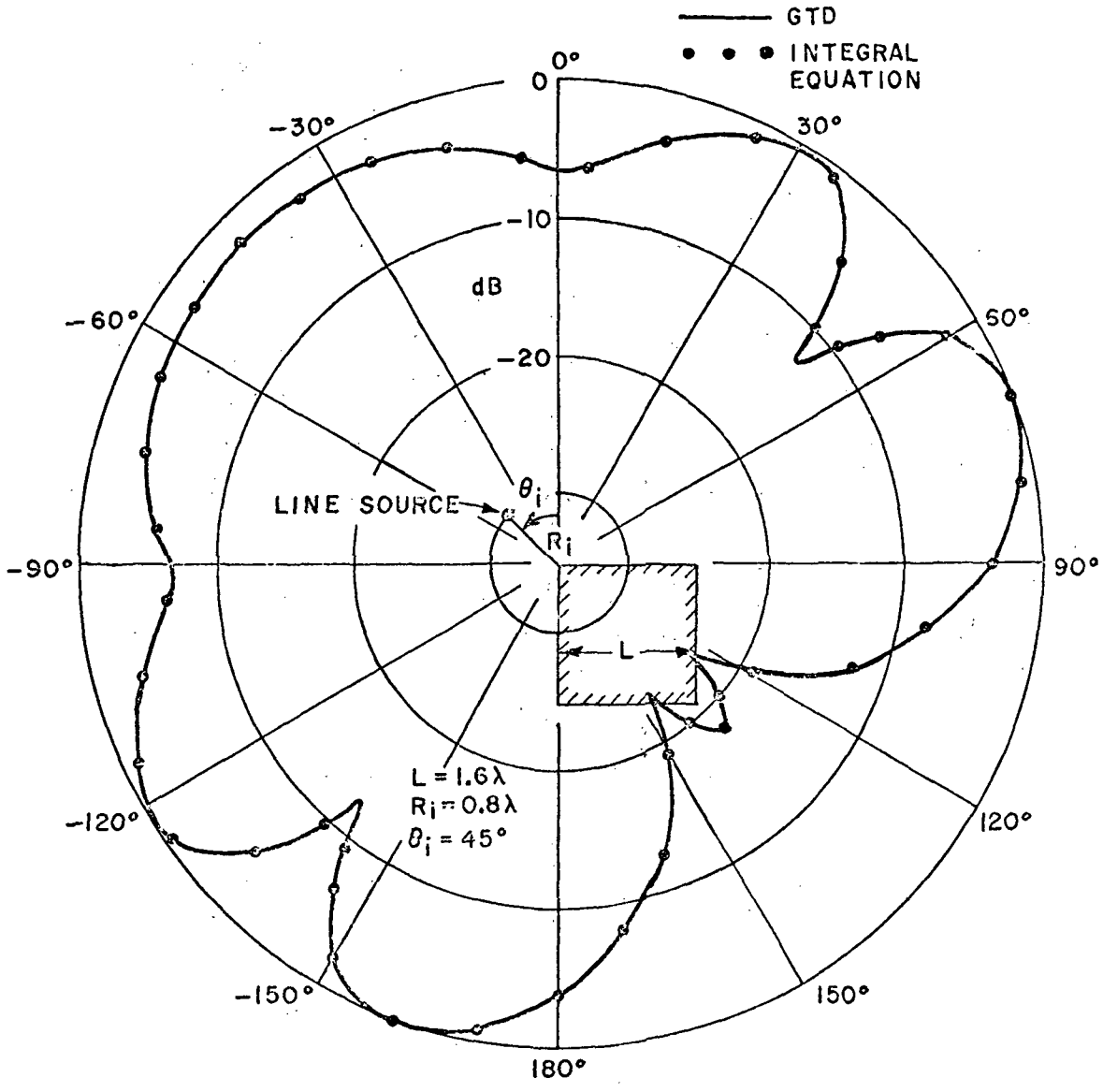

Fig. 11. Pattern of an electric current line source in the presence of a rectangular cylinder.

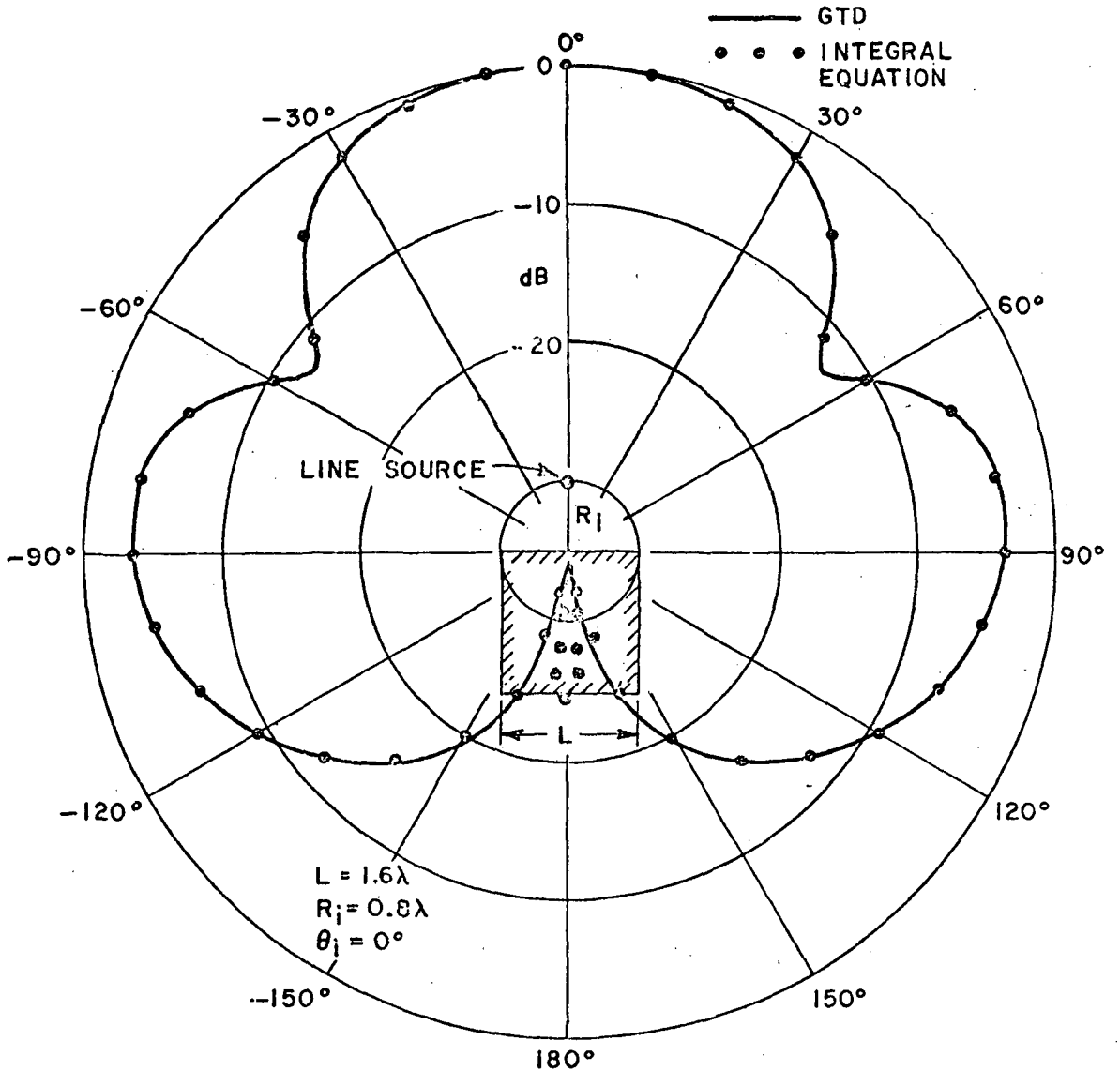

Fig. 12. Pattern of an electric current line source in the presence of a rectangular cylinder.

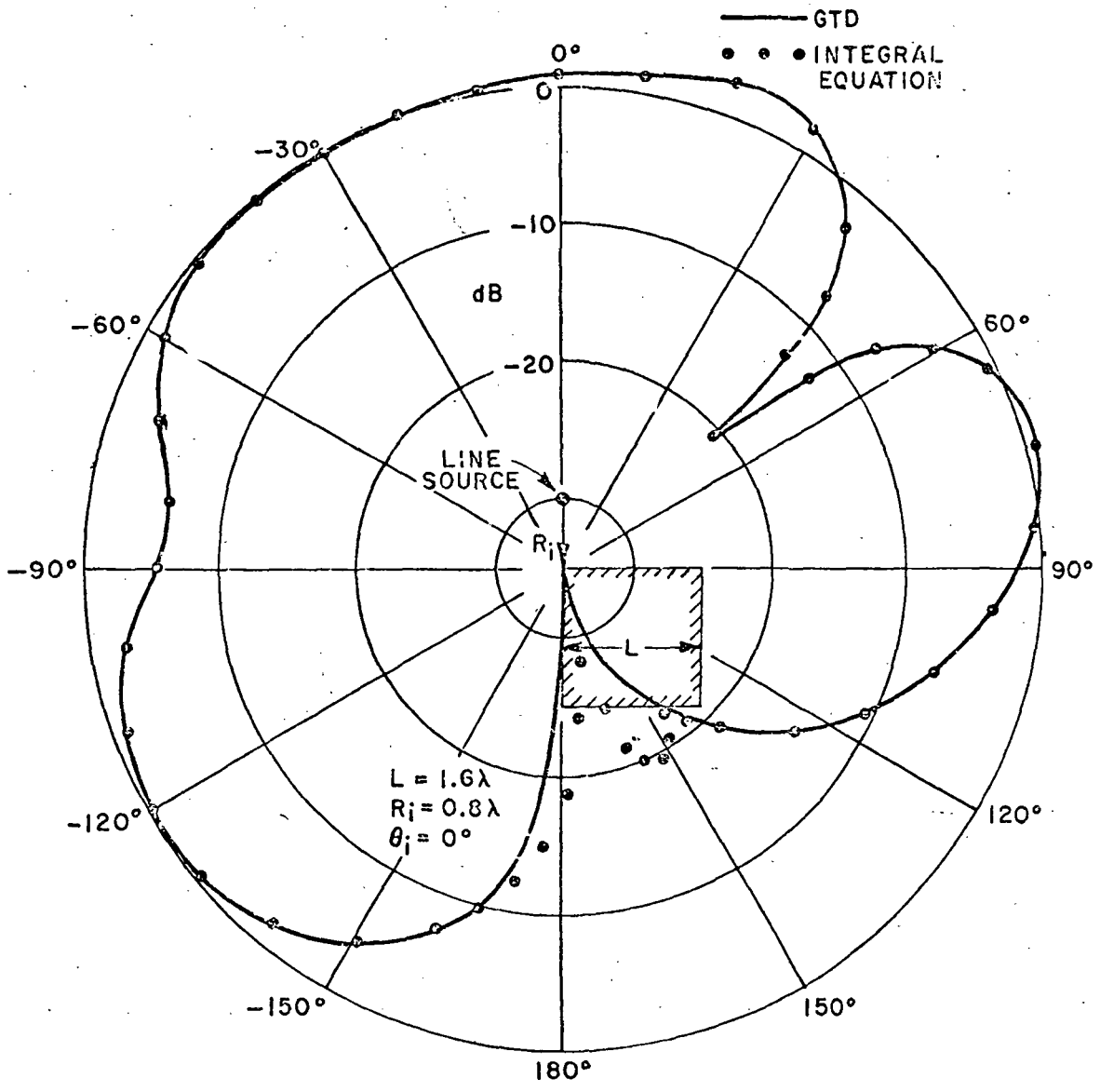

Fig. 13. Pattern of an electric current line source in the presence of a rectangular cylinder.

IV. CONCLUSIONS

The GTD has been applied to calculate the radiation from a perfectly-conducting rectangular cylinder in the presence of a linear array of line sources, which may be of the electric current, magnetic current or magnetic current moment type. When densely packed, these sources may be used to approximate the radiation from an aperture. To insure good accuracy in the fields calculated from the solution described here, the separation of source and field points from the edges of the cylinder and the separation of the edges from each other should be not less than 0.7 wavelength. However, for far-zone pattern calculations, the line sources can be only a few tenth of a wavelength from the nearest edge.

The use of new scalar diffraction coefficients valid in the transition regions makes it possible to calculate continuous patterns in the region surrounding the cylinder away from its edges. Radiation patterns calculated from this solution and from an integral equation solution are found to be in excellent agreement for a number of stringent test cases. This demonstrates the utility and accuracy of the new diffraction coefficients and the overall accuracy of GTD as it has been applied to this problem.

APPENDIX I

THE FIELD AT THE SHADOW BOUNDARY OF A THICK SCREEN FOR GRAZING INCIDENCE

In this appendix we derive an expression for the field near the shadow boundary of a thick, perfectly conducting screen illuminated by a line source at grazing incidence, as shown in Fig. 14. The solution near the shadow boundary in the forward direction is of interest. In the following development we employ Eqs. (5) through (10) in the text, the subscript h on the hard scalar diffraction coefficient has been omitted, and it is convenient to use the function

$$f(x) = \frac{e^{-jkx}}{\sqrt{x}} \tag{A-1}$$

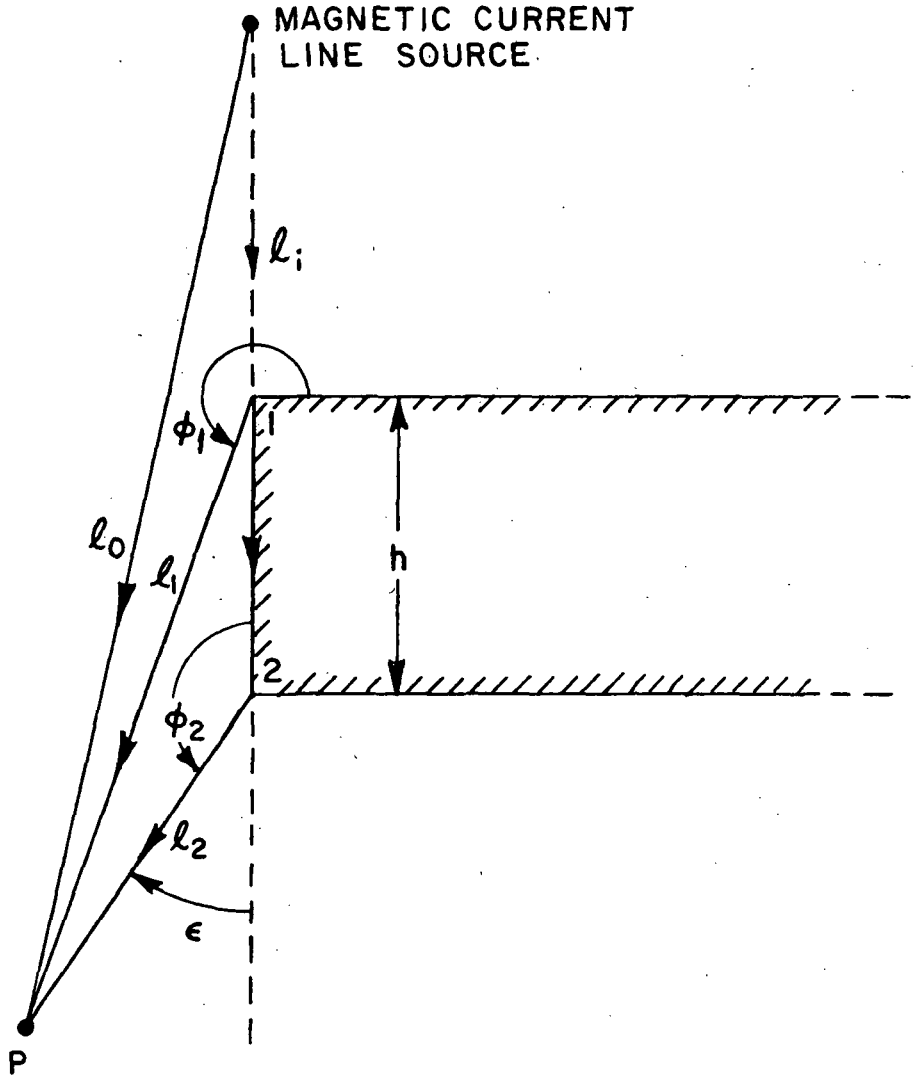

Fig. 14. Shadow boundary of a thick screen for grazing incidence.

Let the strength of the line source be such that the incident field at P is

$$U^i(P) = f(\ell_0) \quad . \tag{A-2}$$

The total field at P is the sum of the incident field plus the field of the ray singly-diffracted from edge 1 and the field of the ray doubly-diffracted from edge 2. In the illuminated region, $\varepsilon > 0$,

$$U(P) = f(\ell_0) + f(\ell_i)\, D(\phi_1, \tfrac{\pi}{2}; L_1)\, f(\ell_1) + \tfrac{1}{2} U^i(2)\, D(\phi_2, 0, L)\, f(\ell_2) \quad . \tag{A-3a}$$

In the shadow region, $\varepsilon < 0$,

$$U(P) = \tfrac{1}{2} U^i(2)\, D(\phi_2, 0, L)\, f(\ell_2) \quad . \tag{A-3b}$$

Here,

$$\phi_2 = \pi - \varepsilon \quad , \tag{A-4a}$$

$$L_1 = \frac{\ell_i\, \ell_1}{\ell_i + \ell_1} \quad , \tag{A-4b}$$

$$U^i(2) = f(\ell_i + h) + f(\ell_i)\left[-\frac{2}{3} e^{-j\,\pi/4} \cot\left(\frac{2\pi}{3}\right) F(2kL_1') \right] f(h) \tag{A-4c}$$

in which

$$L_1' = \frac{\ell_i\, h}{\ell_i + h} \quad . \tag{A-4d}$$

Thus for $\varepsilon > 0$,

$$U(P) = f(\ell_0) + f(\ell_i)\, D(\phi_1, 0; L_1)\, f(\ell_1) + \tfrac{1}{2} f(\ell_i + h)\, D(\phi_2, 0; L_2) f(\ell_2) + \tfrac{1}{2} f(\ell_i) f(h) \left[-\frac{2}{3} e^{-j\,\pi/4} \cot\left(\frac{2\pi}{3}\right) F(2kL_1') \right] D(\phi_2, 0, \overline{L})\, f(\ell_2) \quad , \tag{A-5a}$$

and for $\varepsilon < 0$,

$$\text{(A-5b)} \qquad U(P) = \tfrac{1}{2} f(\ell_i + h)\, D(\phi_2, 0, L_2)\, f(\ell_2) + \tfrac{1}{2} f(\ell_i) f(h) \cdot \left[-\frac{2}{3} e^{-j\pi/4} \cot\left(\frac{2\pi}{3}\right) F(2kL_1') \right] D(\phi_2, 0, \bar{L})\, f(\ell_2) \quad ,$$

where

$$\text{(A-6)} \qquad L_2 = \frac{(\ell_i + h)\, \ell_2}{\ell_i + h + \ell_2}$$

and $\bar{L}$ is a distance parameter determined by the wavefront curvature of the field incident on edge 2 which has been singly-diffracted from edge 1. Since edge 2 is in the transition region of this field, the curvature of this wavefront is not simply that of a cylindrical wave emanating from edge 1; i.e., $\bar{L} \neq h\, \ell_2/(h+\ell_2)$. We will determine $\bar{L}$ by requiring U(P) to be continuous at the shadow boundary.

As $\varepsilon \to 0$,

$$\text{(A-7)} \qquad D(\phi_2, 0, L_2) = \frac{-e^{-j\pi/4}}{n\sqrt{2\pi k}} \left(\frac{2n}{\varepsilon}\right) \sqrt{\frac{\pi k L_2}{2}}\, |\varepsilon|\, e^{j\pi/4}$$

$$= -\sqrt{L_2}\, \operatorname{sgn} \varepsilon \quad .$$

In a similar manner,

$$\text{(A-8)} \qquad D(\phi_2, 0, \bar{L}) = -\sqrt{\bar{L}}\, \operatorname{sgn} \varepsilon \quad .$$

Furthermore, as $\varepsilon \to 0$

$$\text{(A-9)} \qquad D(\phi_1, 0; L_1) = -\frac{2}{3} e^{-j\pi/4} \cot\left(\frac{2\pi}{3}\right) \frac{F(2kL_1)}{\sqrt{2\pi k}}$$

Substituting Eqs. (A-7), (A-8) and (A-9) into Eqs. (A-5a), (A-5b) and requiring U(P) to be continuous at the shadow boundary $\varepsilon = 0$, we see that

$$(A\text{-}10)\quad \frac{e^{jk(\ell_i+\ell_1)}}{\sqrt{\ell_i\ \ell_1}}\left\{-\frac{2}{3}e^{-j\ \pi/4}\cot\left(\frac{2\pi}{3}\right)\frac{F(2kL_1)}{\sqrt{2\pi k}}\right\} =$$

$$\frac{e^{-jk(\ell_i+h+\ell_2)}}{\sqrt{\ell_i\ h\ \ell_2}}\left\{-\frac{2}{3}e^{-j\ \pi/4}\cot\left(\frac{2\pi}{3}\right)\frac{F(2kL_1')}{\sqrt{2\pi k}}\right\}\sqrt{\overline{L}}$$

where $h + \ell_2 = \ell_1$ at $\varepsilon = 0$.

From which

$$(A\text{-}11)\quad \overline{L} = \left(\frac{h\ \ell_2}{h + \ell_2}\right)m$$

with

$$(A\text{-}12)\quad m = \left[\frac{F(2kL_1)}{F(2kL_1')}\right]^2$$

APPENDIX II

DESCRIPTION OF THE COMPUTER PROGRAM

A. Input Variables

N : is the number of sources in the array which approximates the aperture distribution. Here N = 2M+1, where M is an integer (.. N is an odd integer), and M has been introduced earlier in section II. The DIMENSION cards at the beginning of the program must be dimensioned as N or larger.

TYPE : is a reference parameter. TYPE is set equal to 1.0 when sources of type I (see section II) are used. TYPE is likewise set equal to 2.0 for type II, and is set equal to 3.0 for type III sources, respectively.

AL : is the aperture width (= W of Fig. 7).

AM(I): is the magnitude of the Ith source in the array which approximates a given aperture distribution.

AP(I): is the phase of the Ith line source in the array (which approximates a given aperture distribution), in RADIANS.

X : is the point of incidence on the 2-D box and corresponds to X shown in Fig. 7.

XL : is the length of the box (corresponding to XL of Fig. 7).

H : is the height of the box (it corresponds to h in Fig. 7).

RI : is the incident range (corresponding to R_i in Fig. 7).

RS : is the scattered range (corresponding to R_s in Fig. 7).

THI : is the angle of incidence (corresponding to θ_i in Fig. 7).

XLAMDA: is the transmitted wavelength.

Note that the variables AL, XL, H, X, RI and RS have the same units as XLAMDA.

B. Output Variables

THS : is the angle of scattering (corresponding to θ_s in Fig. 7) in degrees.

ATAL : magnitude of the total field.

DBTAL: magnitude of the total field in dB.

DBSAS: magnitude of the scattered field in dB.

DBGA : incident field with phase center at Q (Fig. 7) as a function of THS, in dB.

PHASE: phase of the total field in degrees.

TH : angular variable corresponding to (Fig. 7), in degrees

DBHA : incident field with phase center at O (Fig. 7) in dB, as a function of TH. Note that DBHA is an output variable in the Subroutine TEST.

C. Instructions for Representing Aperture Field Distribution by a 2-D Line Source Array.

When dealing with the input variables AM(I) and AP(I) for Ith source in the planar array used to approximate a given aperture distribution, the ordering of the array elements is done as follows:

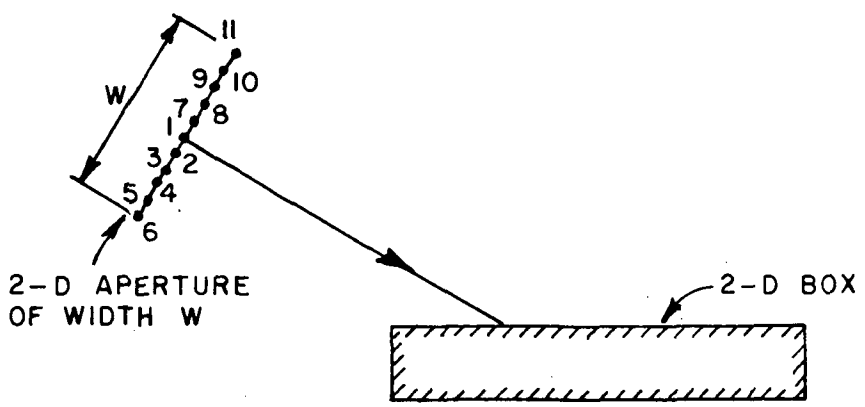

Fig. 15. The ordering arrangement of the line sources used to approximate a given aperture distribution.

Let N = 11, where N is the number of line sources approximating a given aperture distribution over the aperture width W. The ordering arrangement for these sources is indicated in Fig. 15. The source at the center of the aperture is the one for which I = 1. I = 2,3,4,5 and 6 for sources to the right of the one designated by I = 1 (as one views the 2-D box from the aperture center). Similarly, I = 7,8,9,10 and 11 for sources to the left of the source at the center (designated by I = 1).

Let the aperture distribution (assumed known) be represented by the quantity $F = |F|e^{j\psi}$ over the aperture. $|F|$ represents the magnitude of

the field distribution over the width W, and ψ represents the phase of the field distribution over the width W. Hypothetical plots of |F| and ψ over the aperture are indicated below:

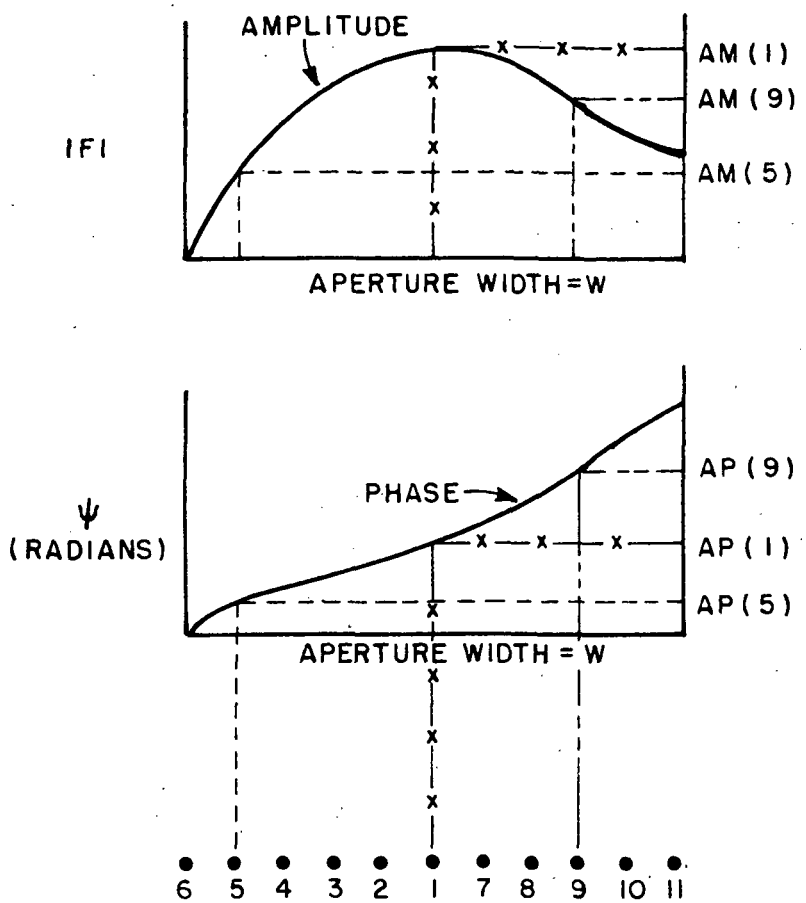

Fig. 16. Field distribution over the aperture.

Fig. 16 clearly indicates the amplitudes and phases of the sources designated by I = 1, 5 and 9. For example, the magnitude of the line source strength corresponding to I = 9 is given by AM(9), and its phase is given by AP(9). Similarly, one can obtain the amplitudes and phases of all the other line sources. Note that the aperture is divided into 2M segments, where M = 5. Hence, the number of sources, N = 2M+1 = 11.

D. Instructions for Using the 'Obliquity Factor'

The fields radiated by apertures are non-symmetrical on either side of the aperture, in most practical cases. The fields radiated by the 2-D line source array discussed above are symmetrical on either side of the planar 2-D array. Thus, an obliquity factor of the type $\cos^n \theta/2$ (please refer to the discussion in section II) is included for computing the field radiated by each source in the array. The obliquity factor is different for each n, where n = 0,½,1,2. A function statement FB(SX) computes this obliquity factor for a given value of n. Specifically, the statement concerning FB(SX) reads:

```
FB(SX) = ABS(COS(SX/2.0))**2.0
```

and corresponds to an obliquity factor with n = 2.0. If any other value of n is desired, the appropriate value must be punched into a new card which replaces the previous one. Note that the value of n directly follows the ** symbol in the statement.

The obliquity factor $\cos^n \theta/2$ is plotted as a function of θ for different values of n (n = ½, 1 and 2) in Fig. 17. When the pattern of an isotropic source is multiplied by $\cos^n \theta/2$, it is evident from the resultant pattern that the obliquity factor serves to control the level of the radiation pattern primarily in the range $\pi/3 < \theta < 5\pi/3$. The case n = 0 corresponds to the isotropic case.

E. Instructions for Computing the Incident Field

Two incident field patterns are computed, one is for a phase reference at the center of the aperture, and the other is for a phase reference at Q (see Fig. 7). In the former case, the radiation pattern in dB is designated by DBHA, and is obtained as a function of θ (or TH as defined in the computer program). In the latter case, the radiation pattern in dB is designated by DBGA and is obtained as a function of θ_S (or THS as defined in the computer program). DBGA is computed at a distance equal to R_S from Q. DBHA has been programmed for a range of $R_i + R_S$ from 0 (center of the aperture as shown in Fig. 7); however, if the user wishes to change the present range for DBHA, only one card in the program deck needs modification. A subroutine designated TEST computes DBHA at a range of $R_i + R_S$ from 0; the call statement for this subroutine is

```
CALL TEST (N, AL, RS+RI, A, TYPE)
```

If a different value of the range is desired, one must replace RS+RI in the call statement above by a number which equals the desired value for the range. Note that the new range should have the same unit as those of λ (corresponding to XLAMDA in the computer program).

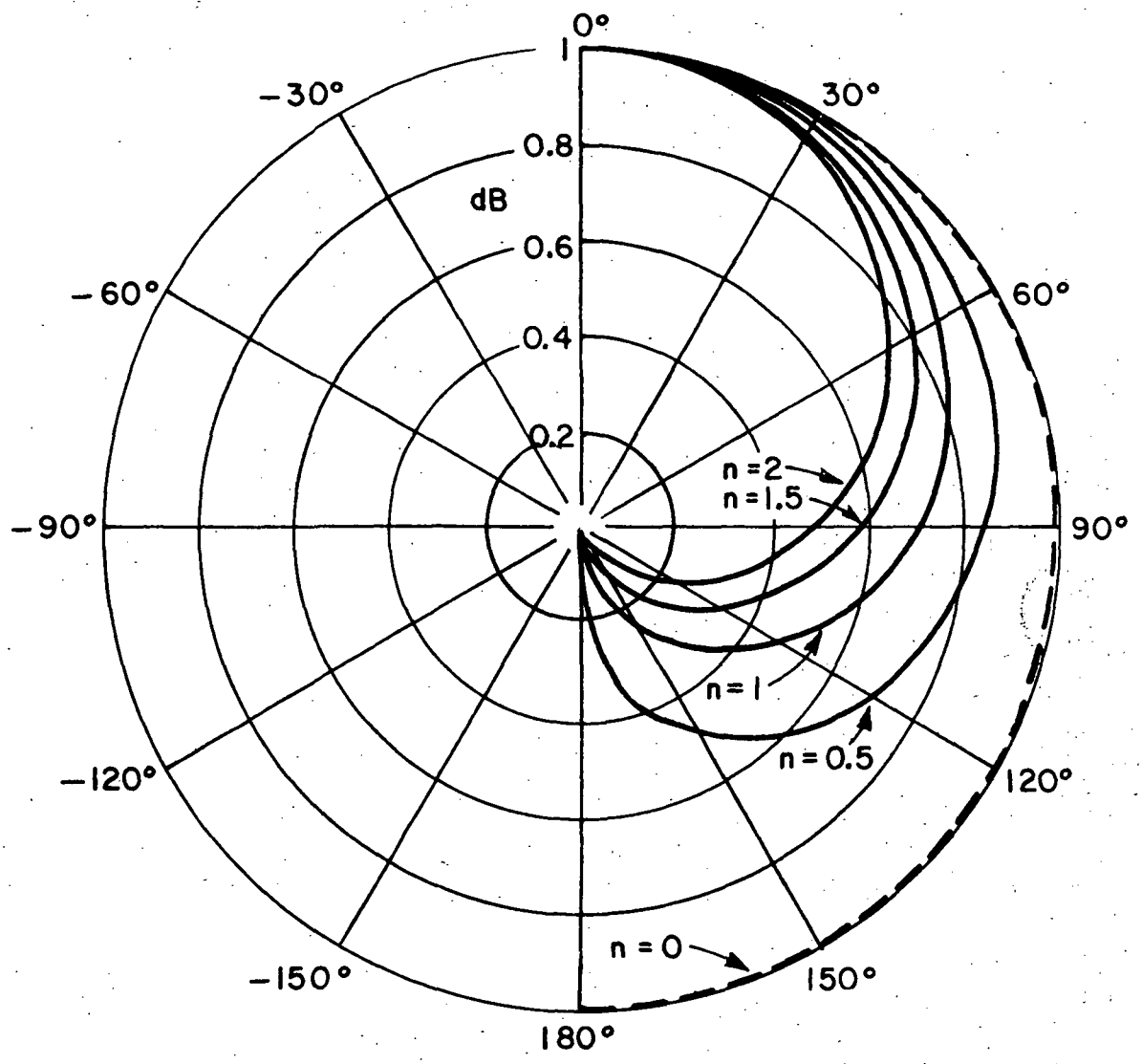

Fig. 17. Patterns of the obliquity factor for different values of n.

F. Sample Programs

In this section, we present a sample case which serves to illustrate the use of our computer program. The example selected involves an array of three magnetic line sources of unit strength which illuminate a rectangular cylinder, as in Fig. 18. We utilize the computer program for calculating the incident field of the array, the field scattered by the 2-D box (rectangular cylinder) and the total field (incident + scattered) surrounding the 2-D box.

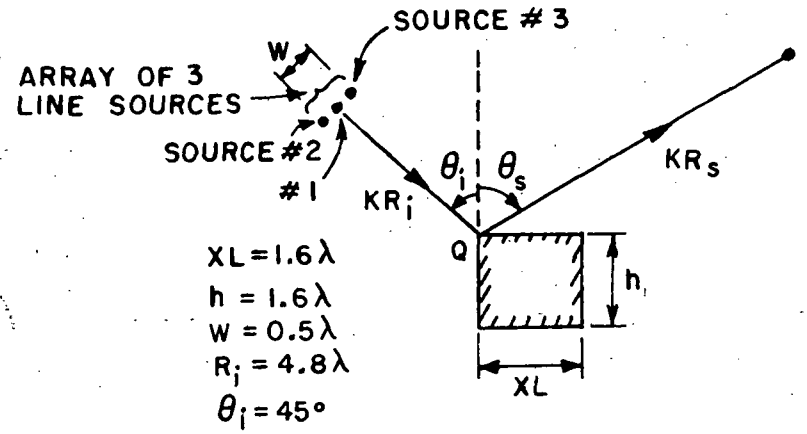

Fig. 18. An array of three line sources in the presence of a square cylinder.

The ordering of the array elements is shown in Fig. 18, where the source at the center is labeled source #1. Note that source #1 corresponds to I = 1, and sources #2 and #3 correspond to I = 2, and I = 3, respectively. For this particular problem, AM(1), AM(2) and AM(3) are each equal to 1.0, and AP(1), AP(2) and AP(3) are each equal to 0.0, because the line sources are of unit strength and zero phase. An obliquity factor corresponding to n = 2 (i.e., obliquity factor = $\cos^2\theta/2$) has been incorporated into the program for the incident field pattern, and the incident field pattern corresponding to DBHA (phase reference at source #1) is plotted in Fig. 19. Also included in Fig. 19 is the incident field pattern without the obliquity factor (n = 0 case) for the sake of comparison. The pattern of the scattered field designated by DBSAS, and computed for values of θ_S (or THS) which lie in the range $-180° \leq \theta_S \leq 180°$, is plotted in Fig. 20. The scattered field obtained by our method is compared against that obtained from a numerical solution to the integral equation for this problem given by J. H. Richmond; these results agree perfectly. Finally, the total field (incident plus scattered, each being phase referenced at Q) is also obtained, and is designated by DBTAL. DBTAL is computed as a function of θ_S (THS in the program) and the results are indicated in Fig. 21 by a dashed curve. The solid curve is added for the sake of comparison; it corresponds to the total field when the incident field has no obliquity factor in it.

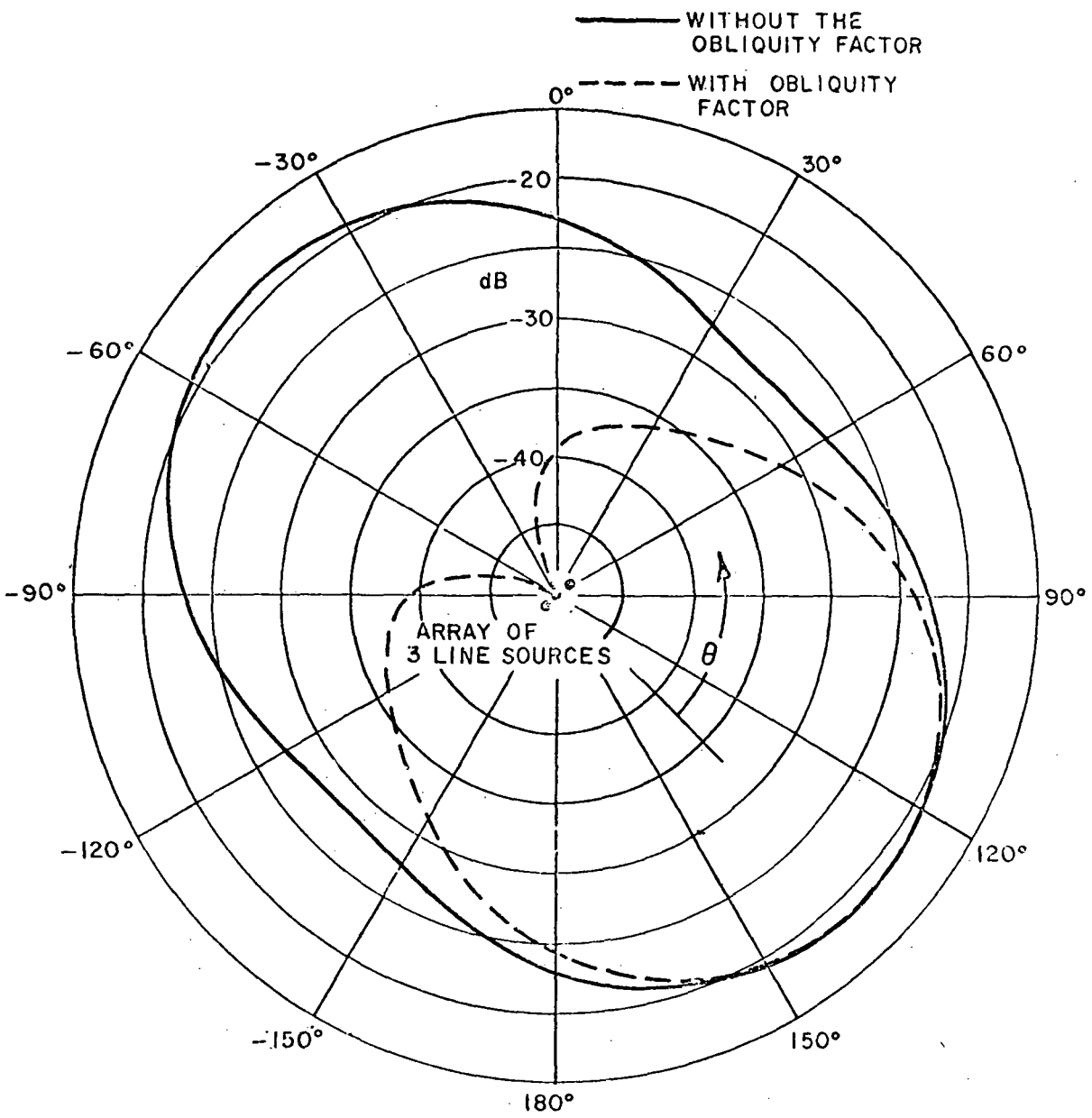

Fig. 19. Patterns of an array of three magnetic line sources of equal strength, with and without the obliquity factor.

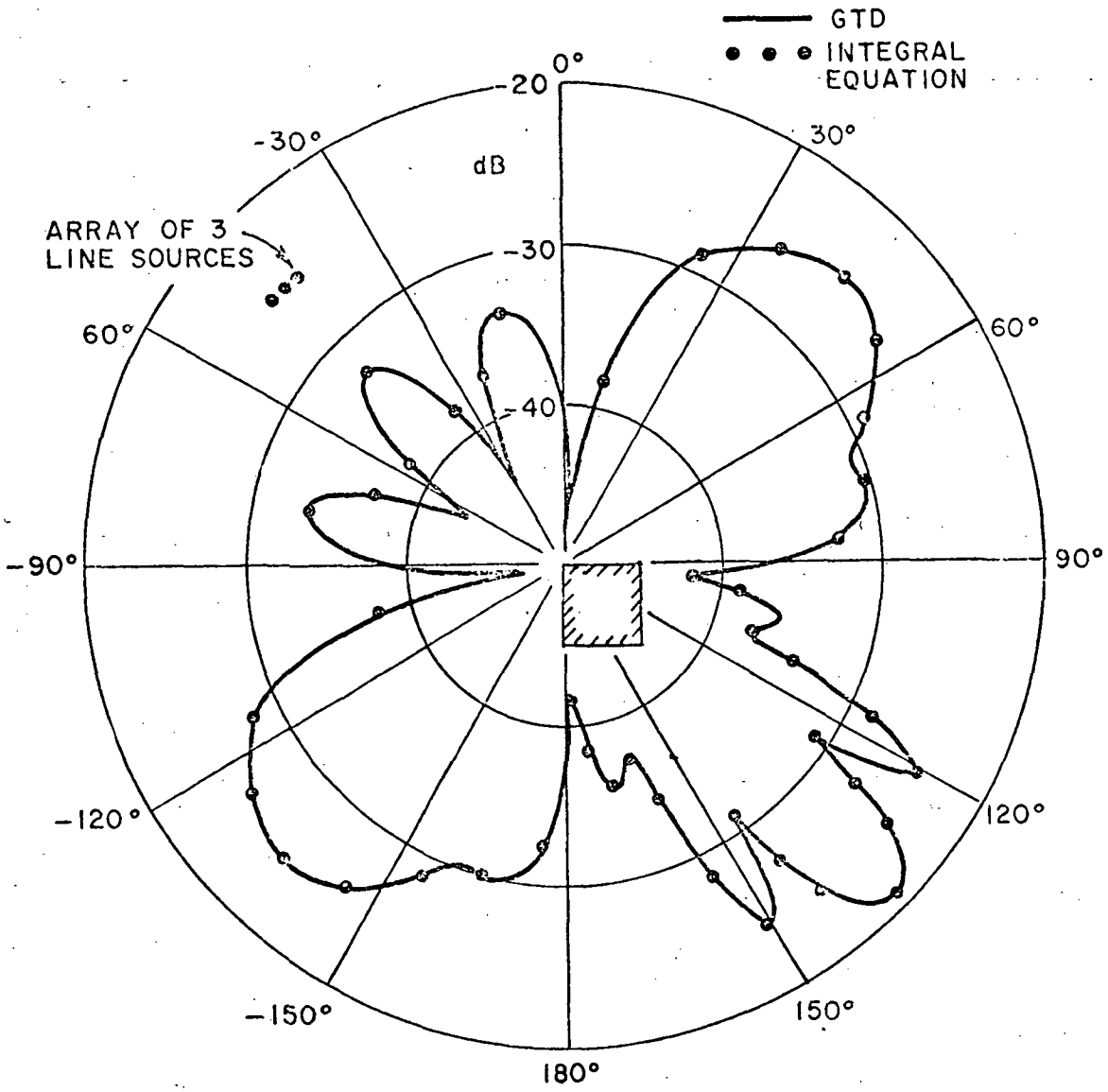

Fig. 20. Pattern of the field scattered by a square cylinder which is illuminated by an array of three magnetic line sources.

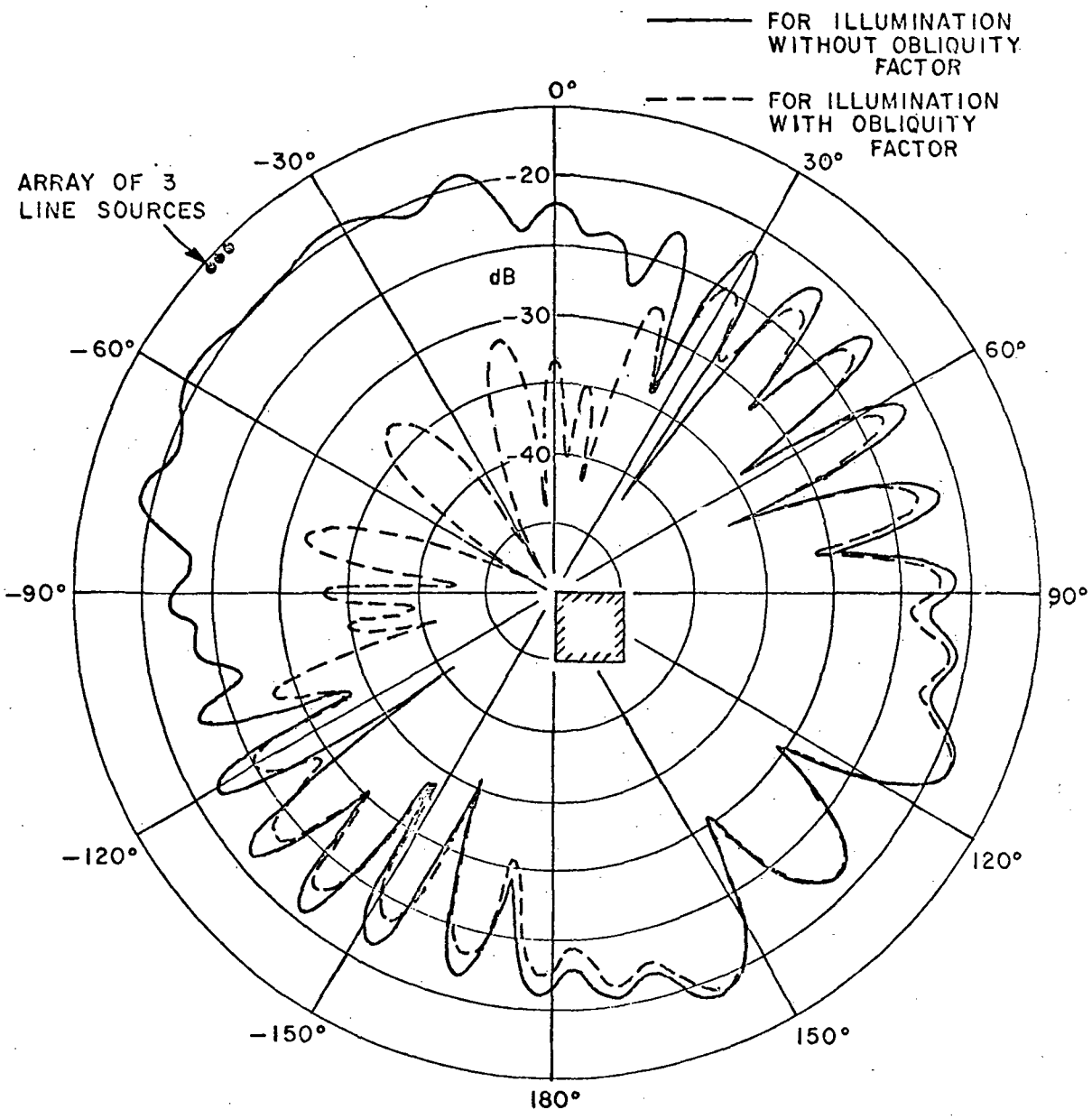

Fig. 21. Pattern of an array of three magnetic line sources in the presence of a square cylinder.

```
      PROGRAM LSOSBOX(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)                    100000
C     PROGRAM LSOSBOX IS PHENIX AUGUST 1972                                     200000
C                                                                               300000
C  N          THE NUMBER OF LINE SOURCES OR ELEMENTS IN THE ARRAY               400000
C  TYPE       1.0 IS ELECTRIC CURRENT LINE SOURCE                               500000
C  TYPE       2.0 IS MAGNETIC CURRENT LINE SOURCE                               600000
C  TYPE       3.0 IS MAGNETIC CURRENT MOMENT LINE SOURCE                        700000
C  AL         APERTURE WIDTH                                                    800000
C  AM(I)      MAGNITUDE OF THE(I)TH ELEMENT                                     900000
C  AP(I)      PHASE OF THE(I)TH ELEMENT                                         1000000
C  A(I)       FIELD STRENGTH OF THE(I)TH ELEMENT                                1100000
C  D(I)       SPACING BETWEEN(I+1)TH AND(I)TH ELEMENTS                          1200000
C  XLAMDA     TRANSMITTED WAVELENGTH                                            1300000
C  X          THE POINT OF INCIDENCE                                            1400000
C  XL         THE LENGTH OF THE BOX                                             1500000
C  H          THE HEIGHT OF THE BOX                                             1600000
C  RI         INCIDENCE RANGE                                                   1700000
C  RS         SCATTERING RANGE                                                  1800000
C  THI        ANGLE OF INCIDENCE  0 TO 65                                       1900000
C  THS        ANGLE OF SCATTERING  -65 TO 65                                    2000000
C  XP,YP      OBSERVING POINT                                                   2100000
C  XS(I),YS(I)   SOURCE POINT OF THE(I)TH ELEMENT                               2200000
C  DS         DIFFRACTION COEFFICIENT FOR SOFT BOUNDARY                         2300000
C  DH         DIFFRACTION COEFFICIENT FOR HARD BOUNDARY                         2400000
C  GA(I)      DIRECT INCIDENT FIELD DUE TO(I)TH ELEMENT                         2500000
C  RA(I)      REFLECTED FIELD DUE TO(I)TH ELEMENT                               2600000
C  DAR1(I)    FIRST ORDER DIFFRACTED FIELD FROM THE RIGHT EDGE DUE TO(I)TH ELEMENT  2700000
C  DAR2(I)    2ND   ORDER DIFFRACTED FIELD FROM THE RIGHT EDGE DUE TO(I)TH ELEMENT  2800000
C  DAR3(I)    3RD   ORDER DIFFRACTED FIELD FROM THE RIGHT EDGE DUE TO(I)TH ELEMENT  2900000
C  DAL1(I)    FIRST ORDER DIFFRACTED FIELD FROM THE LEFT  EDGE DUE TO(I)TH ELEMENT  3000000
C  DAL2(I)    2ND   ORDER DIFFRACTED FIELD FROM THE LEFT  EDGE DUE TO(I)TH ELEMENT  3100000
C  DAL3(I)    3RD   ORDER DIFFRACTED FIELD FROM THE LEFT  EDGE DUE TO(I)TH ELEMENT  3200000
C  TA(I)      THE FIELD AT THE OBSERVING POINT DUE TO(I)TH ELEMENT              3300000
C  TOTAL      TOTAL FIELD AT OBSERVING POINT DUE TO ALL THE ELEMENTS            3400000
C  DBTAL      MAGNITUDE OF THE TOTAL FIELD EXPRESSED IN  DB                     3500000
C  DBSAS      MAGNITUDE OF THE SCATTERED FIELD EXPRESSED IN  DB                 3600000
C  DBHA       DIRECT INCIDENT FIELD EXPRESSED IN  DB                            3700000
C  PHASE      PHASE OF THE TOTAL FIELD EXPRESSED IN  DEGREES                    3800000
C  ATAL  AMPLITUDE OF TOTAL FIELD AND ALSO OF INCIDENT FIELD IN SUBROUTINE TEST 3900000
C                                                                               4000000
000003        DIMENSION  DAL(100)                                               4100000
000003        DIMENSION DAL1(51),DAL2(51),DAL3(51),TA(51)                       4200000
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000003          DIMENSION DLR(51),DRL(51)                                       4300000
000003          DIMENSION CALB(51)                                              4400000
000003          DIMENSION DB2(51)                                               4500000
000003          DIMENSION CA(51),RA(51),DAR1(51),DAR2(51),DAR3(51)              4600000
000003          DIMENSION GGA(51)                                               4700000
000003          DIMENSION RO(51),OB(51)                                         4800000
000003          DIMENSION SAS(51)                                               4900000
000003          DIMENSION THSTFD(185),AMPTFD(185),CBTFD(185),PHTFD(185)         5000000
000003          DIMENSION XS(51),YS(51),AM(51),AP(51),A(51),D(51)               5100000
                C                                                               5200000
000003          COMPLEX A                                                       5300000
000003          COMPLEX  ADDSC(50),CW,CV                                        5400000
000003          COMPLEX  ADDSD(50),CVV,CWW                                      5500000
000003          COMPLEX  CX,CY,CZ,ADDSA(50),ADDSB(50)                           5600000
000003          COMPLEX DB2,ZP,ZQ,ZR,ZS,DBL1,DBL2                               5700000
000003          COMPLEX DLL                                                     5800000
000003          COMPLEX DR1,DR21,DR22,DR31,DR32,DR33,DL1,DL21,DL22,DL31,DL32,DL33  5900000
000003          COMPLEX DX,DY,DS,DZ,GA,RA,DAR1,DAR2,DAR3,DAL1,DAL2,DAL3         6000000
000003          COMPLEX F,CA,CB,DC,DD,DE,DF,DG,DH,DI,DJ,DK,DL,DM,DN,DO,DP,DQ,DR  6100000
000003          COMPLEX FL,PW,HA,HB,HC,HD,PLUS                                  6200000
000003          COMPLEX GGA                                                     6300000
000003          COMPLEX RATAL                                                   6400000
000003          COMPLEX SAS                                                     6500000
000003          COMPLEX SATAL                                                   6600000
000003          COMPLEX TOTAL,U,V,TA                                            6700000
000003          COMPLEX  UU,VV                                                  6800000
000003          COMPLEX ZA,ZB,CAL                                               6900000
000003          COMPLEX ZC,ZD,DRL1,DRL2,ZE,ZF,DRL,ZG,ZH,DLR1,DLR2,DLR,ZN,ZM     7000000
000003          COMPLEX ZX,ZY,DLB,CALB                                          7100000
                C                                                               7200000
000003          COMMON XLAMDA,X,XL,H,RI,RS,THI,UMAX,FIELD,SOURCE                7300000
000003          COMMON/PICONST/PI,    TP,STP,SQRTPI,TT,TTDEG,PI02,PI04          7400000
                C                                                               7500000
000003          FL(X,Y,Z)=2.*CMPLX(0.0,1.0)*SQRT(X)*CEXP(CMPLX(0.0,X))*         7600000
               1SQRT(1.5707963267949)*(.5*CMPLX(1.,-1.)-CMPLX(Y,-Z))            7700000
000057          PW(X)=CEXP(CMPLX(0.0,-6.2831853071796*X))                       7800000
000067          COT(X)=COS(X)/SIN(X)                                            7900000
000077          F(Z)=CEXP( CMPLX(0.,-6.2831853071796*Z))/SQRT(6.2831853071796*Z)  8000000
000121          DS(UU,VV)=SQRT(6.2831853071796)*(UU-VV)                         8100000
000142          DH(UU,VV)=SQRT(6.2831853071796)*(UU+VV)                         8200000
000163          G(W,WW)=W*WW/(W+WW)                                             8300000
000171          FA(SA,SB,SC)= ACOS((SB*SB+SC*SC-SA*SA)/(2.0*SB*SC) )            8400000
000206          FB(SX)=ABS(COS(SX/2.0))**2.0                                    8500000
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C AS(SX) IS THE OBLIQUITY FACTOR.     TO IGNORE IT, SET AS(SX)=1.
C
000221          CALL PSEJOB
000222          READ(5,1110) N, TYPE,AL,SOURCE
000236    1110  FORMAT(I10,2F10.4,A8)
000236          WRITE(6,2110)N,TYPE,AL,SOURCE
000252    2110  FORMAT(//,3X,I2* ELEMENTS*3X*TYPE= *F3.1,3X*APERTURE WIDTH=*F7.4,3X
               1A8* CURRENT LINE SOURCE*/)
000252          READ(5,1114) (  AM(I),AP(I)  ,I=1,N )
000267    1114  FORMAT( 1CF8.4 )
000267          PRINT 2114,  (I,AM(I),AP(I)  ,I=1,N )
000305    2114  FORMAT (/15X*AM*10X*AP*/(5X*N(*I2*)=*2F10.4)))
000305          PRINT 8889
000311    8889  FORMAT (1H1)
000311          NNN=N-1
000313          IF(N.EQ.1) GO TO 6666
000314          DO 1000 JJ=1,N
000316          D(JJ)=AL/FLOAT(NNN)
000321    1000  CONTINUE
000323          GO TO 7777
000323    6666  D(1)=0.0
000324    7777  CONTINUE
000324          DO 1115 M=1,N
000326          A(M)=AM(M)*CEXP( CMPLX(0.0,AP(M) )  )
000343          WRITE(6,665) M,A(M)
000354     665  FORMAT(5X,*A(*I2,*)=*,2F10.4)
000354    1115  CONTINUE
000357    6789  CONTINUE
000357          READ(5,1111)XLAMDA,X,XL,H,RI,RS,THI
000401    1111  FORMAT(7F10.4 )
000401          IF(EOF,5)1112,6790
000404    6790  CONTINUE
000404          WRITE(6,2111) XLAMDA,X,XL,H,RI,RS,THI
000426    2111  FORMAT(1H1,5X,*LAMDA= *,F7.4,*  X= *,F7.4,*  L= *,F7.4,*  H= *,
               1F7.4,*  RI= *,F7.4,*  RS= *,F9.4,*   THI= *,F7.4///// )
C
000426          PI=3.1415926535898
000427          TP=2.*PI
000431          STP=SQRT(TP)
000433          SQRTPI=SQRT(PI)
000435          TT=PI/180.
000437          TTDEG=180./PI
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000440          PIL2=0.5*PI                                                     12900000
000442          PIL4=.25*PI                                                     13000000
000443          WLNORM=1.0/XLAMDA                                               13100000
000445          R=1.0                                                           13200000
                C                                                               13300000
000446          IF(TYPE.NE.2.0) R=-1.0                                          13400000
000452          XLW=XL/XLAMDA                                                   13500000
000453          HW=H/XLAMDA                                                     13600000
000455          THI=THI*TT                                                      13700000
                *                                                               13800000
000457          L=181                                                           13900000
                C    L IS 1.GT.THE NUMBER OF POINTS,NPTS, TO BE PLOTTED         14000000
                C                                                               14100000
000460          THS=181.0                                                       14200000
000462          GO TO 9998                                                      14300000
                *                                                               14400000
000462    9999  CONTINUE                                                        14500000
000462          THS=THS*TTDEG                                                   14600000
000464          ATAL =0.                                                        14700000
000464          CBTAL=0.                                                        14800000
000465          DBGA =0.                                                        14900000
000466          CBSAS=0.                                                        15000000
000467          PHASE=0.                                                        15100000
000471          PRINT 4,    THS,ATAL,CBTAL,DBGA,CBSAS,PHASE                     15200000
000510          IF   ( ATAL.EQ.0.0) GO TO 5                                     15300000
                *                                                               15400000
000511    9998  CONTINUE                                                        15500000
000511          I=1                                                             15600000
000512          THS=THS-2.0                                                     15700000
000514          IF(THS.LT.-180.0) GO TO 1                                       15800000
000516          THS=THS*TT                                                      15900000
000517          XS(I)=X-RI*SIN(THI)                                             16000000
000525          YS(I)=RI*COS(THI)                                               16100000
000532          XP=X+RS*SIN(THS)                                                16200000
000536          YP=RS*COS(THS)                                                  16300000
000541          TE=ATAN2(YP,XP)                                                 16400000
000544          TB=ATAN2(YP,XP-XL)                                              16500000
000552       20 CONTINUE                                                        16600000
000552          TC=ATAN2(YS(I),XL-XS(I) )                                       16700000
000557          TD=ATAN2(YS(I),-XS(I) )                                         16800000
                *                                                               16900000
000564          BOND=0.01*TT                                                    17000000
                *                                                               17100000
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000570          IF( ABS(TE-PIO2  ).LE.BOND ) GO TO  9999                        17200000
000573          IF( ABS(TB-PIO2  ).LE.BOND ) GO TO  9999                        17300000
000577          IF( ABS(TB-TC).LE.BOND ) GO TO 9999                             17400000
000603          IF( ABS(TE-TD).LE.BOND ) GO TO 9999                             17500000
                *                                                               17600000
                C     ANY ONE OF THE 11 IF STATEMENTS ENDING IN GO TO 9999 MAY CAUSE THE  17700000
                C         CURRENT ODD NUMBERED THS ANGLE IN DEG TO BE SKIPPED   17800000
                C                                                               17900000
000607          XR=(XP*YS(I)+XS(I)*YP)/(YS(I)+YP )                              18000000
000616          RO(I)=SQRT((XP-XS(I))*(XP-XS(I))+(YP-YS(I))*(YP-YS(I)))/XLAMDA  18100000
000633          OB(1)=PI                                                        18200000
000634          IF(ABS(THS+THI).GT.BOND) OB(I)=FA(RS,RI,RO(I)*XLAMDA)           18300000
000647          R1=WLNORM     *SQRT( (XR-XS(I))*(XR-XS(I))+(-YS(I))*(-YS(I))  ) 18400000
000660          R2=WLNORM     *SQRT(  (XP-XR)*(XP-XR)+(YP*YP) )                 18500000
000667          R3=WLNORM     *SQRT( (XL-XS(I))*(XL-XS(I))+(-YS(I))*(-YS(I)) )  18600000
000701          R4=WLNORM     *SQRT( (XP-XL)*(XP-XL)+(YP*YP) )                  18700000
000710          R5=WLNORM     *SQRT( (XP-XL)*(XP-XL)+(YP+H )*(YP+H ) )          18800000
000721          R6=WLNORM     *SQRT( (-XS(I))*(-XS(I))+(-YS(I))*(-YS(I)) )      18900000
000732          R7=WLNORM     *SQRT( (XP*XP)+(YP*YP) )                          19000000
000740          R8=WLNORM     *SQRT( (XP*XP)+(YP+H )*(YP+H ) )                  19100000
000747          THR=ATAN2(YP,XP-XR)                                             19200000
000754          R9=WLNORM     *SQRT(XS(I)*XS(I)+(YS(I)+H)*(YS(I)+H) )           19300000
000765          PHP=(PI-ATAN2( YS(I),XS(I)-XL ))*TTDEG                          19400000
000774          PH1=(PI-ATAN2(YP,XP-XL))*TTDEG                                  19500000
001003          PH2=(PI-ATAN2(XP-XL,-H-YP))*TTDEG                               19600000
001014          PH3=270.0-PH1                                                   19700000
001016          THP=(ATAN2(YS(I),XS(I)) )*TTDEG                                 19800000
001022          TH1=(PI-ATAN2(YP,-XP))*TTDEG                                    19900000
001030          TH2=(PI-ATAN2(-XP,-H-YP))*TTDEG                                 20000000
001041          TH3=270.0-TH1                                                   20100000
001043          TH4=ATAN2(-XS(I),YS(I)+H)                                       20200000
                C                                                               20300000
001052          IF(XS(I).LT.0.0.AND.ABS((THI-THS)/TT-180.0).LE.1.0) GO TO 9999  20400000
001067          IF(XS(I).GE.0.0.AND.ABS(TH1-THP-180.0).EQ.0.0) GO TO 9999       20500000
001101          IF(XS(I).LT.0.0.AND.ABS(TH2-TH4/TT-180.0).EQ.0.0) GO TO 9999    20600000
001113          IF(ABS(PH1-PHP-180.0).EQ.0.0) GO TO 9999                        20700000
                C                                                               20800000
001116          QA=G(R3,R4 )                                                    20900000
001121          CALL DFRCF(DA,1.5,QA,PH1-PHP, 1.)                               21000000
001126          CALL DFRCF(DB,1.5,QA,PH1+PHP, 1.)                               21100000
001134          DR1 =DH(DA,DB)                                                  21200000
                **                                                              21300000
                **                                                              21400000
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001143          IF(TYPE.NE.2.0) DR1=DS(DA,DB)                                   21500000
001154          QB=G(R3,HW)                                                     21600000
001157          CALL DFRCF(DC,1.5,QB,270.00-PHP,1. )                            21700000
001164          CALL DFRCF(DD,1.5,QB,270.00+PHP,1. )                            21800000
001172          DR21=DH(DC,DD)                                                  21900000
001201          IF(TYPE.NE.2.0) DR21=DS(DC,DD)                                  22000000
001212          QC=G(HW,R5)                                                     22100000
001215          CALL DFRCF(DE,1.5,QC,PH2+0.0,1. )                               22200000
001222          CALL DFRCF(DF,1.5,QC,PH2-0.0,1.)                                22300000
001230          DR22=DH(DE,DF)                                                  22400000
001237          IF(TYPE.NE.2.0) DR22=DS(DE,DF)                                  22500000
001250          DR31=DR21                                                       22600000
001253          CALL DFRCF(DG,1.5,HW,0.0,1.0 )                                  22700000
001256          CALL DFRCF(DZ,1.5,HW,0.0,1.0 )                                  22800000
001262          DR32=DH(DG,DZ)                                                  22900000
001271          IF(TYPE.NE.2.0) DR32=DS(DG,DZ)                                  23000000
001302          QD=G(HW,R4)                                                     23100000
001305          CALL DFRCF(DI,1.5,QD,PH3,1.0 )                                  23200000
001310          CALL DFRCF(DJ,1.5,QD,PH3,1.0 )                                  23300000
001314          DR33=DH(DI,DJ)                                                  23400000
001323          IF(TYPE.NE.2.0) DR33=DS(DI,DJ)                                  23500000
001334          QE=G(R6,R7)                                                     23600000
001337          CALL DFRCF(DK,1.5,QE,TH1-THP,1.0 )                              23700000
001344          CALL DFRCF(DL,1.5,QE,TH1+THP,1.0 )                              23800000
001352          DL1 =DH(DK,DL)                                                  23900000
001361          IF(TYPE.NE.2.0)  DL1=DS(DK,DL)                                  24000000
001372          QF=G(R6,HW)                                                     24100000
001375          CALL DFRCF(DM,1.5,QF,270.00-THP,1.0 )                           24200000
001402          CALL DFRCF(DN,1.5,QF,270.00+THP,1.0 )                           24300000
001410          DL21=DH(DM,DN)                                                  24400000
001417          IF(TYPE.NE.2.0) DL21=DS(DM,DN)                                  24500000
001430          QG=G(HW,R8)                                                     24600000
001433          CALL DFRCF(DO,1.5,QG,TH2,1.0 )                                  24700000
001436          CALL DFRCF(DP,1.5,QG,TH2,1.0 )                                  24800000
001442          DL22=DH(DO,DP)                                                  24900000
001451          IF(TYPE.NE.2.0) DL22=DS(DO,DP)                                  25000000
001462          DL31=DL21                                                       25100000
001465          CALL DFRCF(DQ,1.5,HW,0.0,1.0 )                                  25200000
001470          CALL DFRCF(DR,1.5,HW,0.0,1.0 )                                  25300000
001474          DL32=DH(DQ,DR)                                                  25400000
001503          IF(TYPE.NE.2.0) DL32=DS(DQ,DR)                                  25500000
001514          QI=G(HW,R7)                                                     25600000
001517          CALL DFRCF(DX,1.5,QI,TH3,1.0 )                                  25700000
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                CALL DFRCF(DY,1.5,QI,TH3,1.0 )                                                    25900000
001525          DL33=DH(DX,DY)                                                                    25900000
001535          IF(TYPE.NE.2.0) DL33=DS(DX,DY)                                                    26000000
001546          QK=G(R8,R9)                                                                       26100000
001551          CALL DFRCF(ZA,1.5,QK,TH2-TH4/TT,1.0)                                              26200000
001557          CALL DFRCF(ZB,1.5,QK,TH2+TH4/TT,1.0)                                              26300000
001566          DLL=DH(ZA,ZB)                                                                     26400000
001575          IF(TYPE.NE.2.0)  DLL=DS(ZA,ZB)                                                    26500000
001606          DAL(I)=A(I)*F(R9)*DLL*F(R8)                                                       26600000
001632          CAL(I)=CAL(I)*FB(THI-TH4)                                                         26700000
001642          GA(I)=A(I)*F(RO(I))                                                               26800000
001655          GA(I)=GA(I)*FB(GB(I))                                                             26900000
001665          RA(I)=A(I)*R*F(R1+R2)                                                             27000000
001701          RA(I)=RA(I)*FB(THI-ATAN2(YS(I),ABS(XR-XS(I))))                                    27100000
001717          DAR1(I)=A(I)*F(R3)*DR1*F(R4)                                                      27200000
001743          DAR1(I)=DAR1(I)*FB(0.5*PI-THI-PHP*TT)                                             27300000
001756          DAR2(I)=A(I)*F(R3)*DR21*F(HW)*0.5*DR22*F(R5)                                      27400000
002014          DAR2(I)=DAR2(I)*FB(0.5*PI-THI-PHP*TT)                                             27500000
002027          DAL1(I) =A(I)*F(R6)*DL1*F(R7)                                                     27600000
002053          DAL1(I)=DAL1(I)*FB(0.5*PI+THI-THP*TT)                                             27700000
002066          DAL2(I)=A(I)*F(R6)*DL21*F(HW)*0.5*DL22*F(R8)                                      27800000
002124          DAL2(I)=DAL2(I)*FB(0.5*PI+THI-THP*TT)                                             27900000
002137          IF(XS(I).EQ.0.0) DAL2(I)=0.5*DAL(I)                                               28000000
002147          YL2=G(R8,R6+H)                                                                    28100000
002153          XF=2.0*G(R6,H+R8)                                                                 28200000
002161          CALL CS(C,S,XF)                                                                   28300000
002163          CALL WANG(TH2,0.0,1.5,YL2,HA,HB)                                                  28400000
002167          CALL WANG(270.0,0.0,1.5,YL2,HC,HD)                                                28500000
002173          PLUS=A(I)*F(R6)*FL(XF,C,S)*COT(TP/3.0)*PW(0.125)*F(HW)/3.0/STP                    28600000
002243          IF(TYPE.NE.2.0) HA=HB                                                             28700000
002247          IF(XS(I).EQ.0.0) DAL2(I)=DAL2(I)-PLUS*HA*F(R8)                                    28800000
                C                                                                                 28900000
002270          IF(XS(I).EQ.0.0.AND.TYPE.EQ.1.0) DAL2(I)=CMPLX(0.0,0.0)                           29000000
002306          IF(XS(I).GE.0.0) DAL(I)=CMPLX(0.0,0.0)                                            29100000
                C                                                                                 29200000
002316          DAL3(I)=CMPLX(0.0,0.0)                                                            29300000
002325          DAR3(I)=CMPLX(0.0,0.0)                                                            29400000
                C                                                                                 29500000
002333          WX=G(R9,HW)                                                                       29600000
002335          CALL DFRCF(ZX,1.5,WX,0.0-TH4/TT,1.0)                                              29700000
002343          CALL DFRCF(ZY,1.5,WX,0.0+TH4/TT,1.0)                                              29800000
002352          DLB=DH(ZX,ZY)                                                                     29900000
002361          IF(TYPE.NE.2.0)  DLB=DS(ZX,ZY)                                                    30000000
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002372          DALB(I)=A(I)*F(R9)*DLB*0.5*F(HW)*DL33*F(R7)                     30100000
002430          DALB(I)=DALB(I)*FB(THI-TH4)                                     30200000
002440          IF(XS(I).GT.0.0) DALB(I)=CMPLX(0.0,0.0)                         30300000
002450          IF(TH1.GT.270..AND.TH1.LT.360.) DALB(I)=CMPLX(0.0,0.0)          30400000
C                                                                               30500000
002467          R10=SQRT((XP-XL)*(XP-XL)+(YP+H)*(YP+H))/XLAMDA                  30600000
002500          TH5=(PI-ATAN2(-YP,XP-XL))*TTDEG                                 30700000
002510          PA=G(R9,XLW)                                                    30800000
002513          CALL DFRCF(ZP,1.5,PA,270.0-TH4/TT,1.0)                          30900000
002521          CALL DFRCF(ZQ,1.5,PA,270.0+TH4/TT,1.0)                          31000000
002530          DBL1=DH(ZP,ZQ)                                                  31100000
002537          IF(TYPE.NE.2.0) DBL1=DS(ZP,ZQ)                                  31200000
002550          PB=G(XLW,R10)                                                   31300000
002553          CALL DFRCF(ZR,1.5,PB,0.0-TH5,1.0)                               31400000
002560          CALL DFRCF(ZS,1.5,PB,0.0+TH5,1.0)                               31500000
002566          DBL2=DH(ZR,ZS)                                                  31600000
002575          IF(TYPE.NE.2.0) DBL2=DS(ZR,ZS)                                  31700000
002606          DB2(I)=A(I)*F(R9)*DBL1*F(XLW)*0.5*DBL2*F(R10)                   31800000
002644          DB2(I)=DB2(I)*FB(THI-TH4)                                       31900000
002654          IF(XS(I).GT.0.0) DB2(I)=CMPLX(0.0,0.0)                          32000000
002664          IF(XS(I).EQ.0.0) DB2(I)=0.5*DB2(I)                              32100000
002674          IF(TYPE.NE.2.0) HC=HD                                           32200000
002701          IF(XS(I).EQ.0.0) DB2(I)=DB2(I)-PLUS*HC*F(XLW)*DBL2*F(R10)       32300000
002733          IF(TH5.GT.270.0.AND.TH5.LT.360.0) DB2(I)=CMPLX(0.0,0.0)         32400000
002752          QX=G(R3,XLW)                                                    32500000
002755          CALL DFRCF(ZG,1.5,QX,0.0-PHP,1.0)                               32600000
002762          CALL DFRCF(ZH,1.5,QX,0.0+PHP,1.0)                               32700000
002770          DLR1=DH(ZG,ZH)                                                  32800000
002777          IF(TYPE.NE.2.0) DLR1=DS(ZG,ZH)                                  32900000
003010          QW=G(R7,XLW)                                                    33000000
003013          CALL DFRCF(ZM,1.5,QW,TH1,1.0)                                   33100000
003016          CALL DFRCF(ZN,1.5,QW,TH1,1.0)                                   33200000
003022          DLR2=DH(ZM,ZN)                                                  33300000
003031          IF(TYPE.NE.2.0) DLR2=DS(ZM,ZN)                                  33400000
003042          DLR(I)=A(I)*F(R3)*DLR1*F(XLW)*0.5*DLR2*F(R7)                    33500000
003100          DLR(I)=DLR(I)*FB(0.5*PI-THI-PHP*TT)                             33600000
003113          IF(TH1.GE.270.0.AND.TH1.LT.360.) DLR(I)=CMPLX(0.0,0.0)          33700000
003131          QZ=G(R6,XLW)                                                    33800000
003134          CALL DFRCF(ZC,1.5,QZ,0.0-THP,1.0)                               33900000
003141          CALL DFRCF(ZD,1.5,QZ,0.0+THP,1.0)                               34000000
003147          DRL1=DH(ZC,ZD)                                                  34100000
003156          IF(TYPE.NE.2.0) DRL1=DS(ZC,ZD)                                  34200000
003157          QY=G(XLW,R4)                                                    34300000
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003172          CALL DFRCF(ZE,1.5,QY,PHL,1.0)                                   34400000
003175          CALL DFRCF(ZF,1.5,CY,PH1,1.0)                                   34500000
003201          DRL2=DH(ZF,ZF)                                                  34600000
003210          IF(TYPE.NE.2.0) DRL2=CS(ZE,ZF)                                  34700000
          **                                                                    34800000
          **                                                                    34900000
003221          DRL(I)=A(I)*F(R6)*DRL1*F(XLW)*0.5*DRL2*F(R4)                    35000000
003257          DRL(I)=DRL(I)*FB(0.5*PI+THI-THP*TT)                             35100000
003272          IF(PHL.GE.270.0.AND.PHL.LT.360.) DRL(I)=CMPLX(0.0,0.0)          35200000
003310          ADDSA(I)=CMPLX(0.0,C.0)                                         35300000
003317          CALL KKDC(CX,1.5,QK,0.0,TH2,1.0,1)                              35400000
          *                                                                     35500000
          *                                                                     35600000
003325          IF(TYPE.EQ.1.0.AND.TH2.GT.0.0.AND.TH2.LT.270.0.AND.XS(I).EQ.0.0)35700000
         1ADDSA(I)=A(I)*F(R9)*0.5*SQRT(TP)*CX*F(R8)/CMPLX(0.0,R9*TP)*2.0        35800000
003406          ADDSB(I)=CMPLX(0.0,C.0)                                         35900000
003415          CALL KKDC(CY,1.5,QB,PHP,270.0,1.0,0)                            36000000
003423          CALL KKDC(CZ,1.5,QC,0.0,270.0-TH5,1.0,1)                        36100000
003434          IF(TYPE.EQ.1.0.AND.TH5.GT.0.0.AND.TH5.LT.270.0)                 36200000
         1ADDSB(I)=A(I)*F(R3)*F(HW)*CY*TP*0.5*CZ*F(R10)/CMPLX(0.0,HW*TP)        36300000
003515          ADDSC(I)=CMPLX(0.0,0.0)                                         36400000
003524          CALL KKDC(CV,1.5,QF,90.0,270.0,1.0,0)                           36500000
003532          CALL KKDC(CW,1.5,QG,0.0,TH2,1.0,1)                              36600000
003541          IF(TYPE.EQ.1.0.AND.TH2.GT.0.0.AND.TH2.LT.270.0.AND.XS(I).EQ.0.0)36700000
         1ADDSC(I)=A(I)*F(R6)*CV*F(HW)*0.5*CW*F(R8)/CMPLX(0.0,TP*HW)            36800000
003626          ADDSC(I)=ADDSC(I)*TP                                            36900000
003633          ADDSD(I)=CMPLX(0.0,0.0)                                         37000000
003642          CALL KKDC(CVV,1.5,QX,PHP,0.0,1.0,0)                             37100000
003650          CALL KKDC(CWW,1.5,QW,0.0,TH1,1.0,1)                             37200000
003657          IF(TYPE.EQ.1.0.AND.TH1.GT.0.0.AND.TH1.LT.270.0)                 37300000
         1ADDSD(I)=A(I)*F(R3)*CVV*F(XLW)*0.5*CWW*F(R7)/CMPLX(0.0,XLW*TP)        37400000
          *                                                                     37500000
          *                                                                     37600000
003737          ADDSC(I)=ADDSD(I)*TP                                            37700000
          ***                                                                   37800000
003744          IF(TYPE.EQ.3.0.AND.DB(I).LT.PI/2.0) GA(I)=GA(I)*COS(DB(I))      37900000
003765          IF(TYPE.EQ.3.0.AND.DB(I).GT.PI/2.0) GA(I)=GA(I)*COS(PI-DB(I))   38000000
004011          GGA(I)=GA(I)                                                    38100000
004015          IF(TYPE.EQ.3.0)   RA(I)=RA(I)*COS(THI-ATAN2(YS(I),ABS(XR-XS(I))))38200000
004037          IF(TYPE.EQ.3.0)   DAL(I)=DAL(I)*COS(THI-TH4)                    38300000
004053          IF(TYPE.EQ.3.0) DAR1(I)=DAR1(I)*COS(0.5*PI-THI-PHP*TT)          38400000
004072          IF(TYPE.EQ.3.0) DAR2(I)=DAR2(I)*COS(0.5*PI-THI-PHP*TT)          38500000
004111          IF(TYPE.EQ.3.0) DALL(I)=DALL(I)*COS(0.5*PI+THI-THP*TT)          38600000
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004130          IF(TYPE.EQ.3.0) DAL2(I)=DAL2(I)*COS(0.5*PI+THI-THP*TT)                  38700000
004147          IF(TYPE.EQ.3.0) DALB(I)=DALB(I)*COS(THI-TH4)                            38800000
004163          IF(TYPE.EQ.3.0)  DB2(I)= DB2(I)*COS(THI-TH4)                            38900000
004177          IF(TYPE.EQ.3.0)  DLR(I)=DLR(I)*COS(0.5*PI-THI-PHP*TT)                   39000000
004216          IF(TYPE.EQ.3.0)  DRL(I)=DRL(I)*COS(0.5*PI+THI-THP*TT)                   39100000
      ***                                                                               39200000
004235          IF(YP.GT.0.0) GO TO 3333                                                39300000
004240          RA(I)=CMPLX(0.0,0.0)                                                    39400000
      *                                                                                 39500000
004246          IF(XS(I).GE.0.0.AND.PHI-PHP.EQ.180.0.OR .THI-THP.EQ.180.)               39600000
               1 GO TO 9999                                                             39700000
      *                                                                                 39800000
004264          IF(XS(I).GE.0.0.AND.PHI-PHP.GE.180.0.AND.THI-THP.GE.180.)GA(I)=         39900000
               1CMPLX(0.0,0.0)                                                          40000000
      *                                                                                 40100000
004312          IF(XS(I).LT.0.0.AND.PHI-PHP.EQ.180.0.OR .(TH2-TH4/TT).EQ.180.0)         40200000
               1 GO TO 9999                                                             40300000
      *                                                                                 40400000
004331          IF(XS(I).LT.0.0.AND.PHI-PHP.GT.180.0.AND.(TH2-TH4/TT).GT.180.0)         40500000
               1 GA(I)=CMPLX(0.0,0.0)                                                   40600000
004356          IF(PHI.GT.270.0.AND.PHI.LT.360.0) DAR1(I)=CMPLX(0.0,0.0)                40700000
004375          IF(THI.GT.270.0.AND.THI.LT.360.0) DAL1(I)=CMPLX(0.0,0.0)                40800000
004414          IF(PH2.GE.270.0.AND.PH2.LT.360.0) DAR2(I)=CMPLX(0.0,0.0)                40900000
004433          IF(TH2.GE.270.0.AND.TH2.LT.360.0) DAL2(I)=CMPLX(0.0,0.0)                41000000
004452          IF(TH3.LE.0.0) DAL3(I)=CMPLX(0.0,0.0)                                   41100000
004463          IF(PH3.LE.0.0) DAR3(I)=CMPLX(0.0,0.0)                                   41200000
004474          IF(TH2.GE.270.0.AND.TH2.LT.360.0) DAL(I)=CMPLX(0.0,0.0)                 41300000
004513          IF(XS(I).LT.0.0.AND.XP.LT.0.0) RA(I)=A(I)*R*F(SQRT((XS(I)+XP)*          41400000
               1(XS(I)+XP)+(YS(I)-YP)*(YS(I)-YP))/XLAMDA)                               41500000
004550          YR=YP-XP*(YP-YS(I))/(XP+XS(I))                                          41600000
      *                                                                                 41700000
004557          IF(YP.EQ.-H.OR.YR.EQ.0.0) GO TO 9999                                    41800000
      *                                                                                 41900000
004566          IF(XS(I).LT.0.0.AND.XP.LT.0.0)                                          42000000
               1RA(I)=RA(I)*FB(ATAN2(-XS(I),YS(I)-YR)-THI)                              42100000
004612          IF(XS(I).LT.0.0.AND.XP.LT.0.0.AND.TYPE.EQ.3.0)                          42200000
               1RA(I)=RA(I)*COS(THI-ATAN2(-XS(I),YS(I)-YR))                             42300000
004645          IF(YR.LE.-H.OR.YR.GE.0.0) RA(I)=CMPLX(0.0,0.0)                          42400000
004664          TA(I)=GA(I)+RA(I)+DAR1(I)+DAR2(I)+DAR3(I)+DAL1(I)+DAL2(I)+DAL3(I)       42500000
               1+DAL(I)                                                                 42600000
004723          TA(I)=TA(I)+DLR(I)+DRL(I)                                               42700000
004734          TA(I)=TA(I)+DB2(I)                                                      42800000
004742          TA(I)=TA(I)+DALB(I)                                                     42900000
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                SAS(I)=TA(I)-GA(I)                                                43000000
004757          TA(I)=TA(I)+ADDSA(I)                                              43100000
004765          TA(I)=TA(I)+ADDSB(I)                                              43200000
004773          TA(I)=TA(I)+ADDSC(I)                                              43300000
005001          TA(I)=TA(I)+ADDSD(I)                                              43400000
005007          GO TO 4444                                                        43500000
005007     3333 CONTINUE                                                          43600000
005007          TA(I)=GA(I)+RA(I)+DAR1(I)+DAR2(I)+DAR3(I)+DAL1(I)+DAL2(I)+DAL3(I) 43700000
005042          TA(I)=TA(I)+DLR(I)+CRL(I)                                         43800000
005053          TA(I)=TA(I)+DB2(I)                                                43900000
005061          TA(I)=TA(I)+DALB(I)                                               44000000
005067          TA(I)=TA(I)+ADDSA(I)                                              44100000
005075          TA(I)=TA(I)+ADDSB(I)                                              44200000
005103          TA(I)=TA(I)+ADDSC(I)                                              44300000
005111          TA(I)=TA(I)+ADDSD(I)                                              44400000
005117          IF(XP.GT.XL.AND.TB.LT.TC) TA(I)=TA(I)-RA(I)-DAL2(I)               44500000
005141          IF(XS(I).GT.0.0.AND.XP.GT.XL.AND.TB.GT.TC) TA(I)=TA(I)-DAL2(I)    44600000
005164          IF(XS(I).GT.0.0.AND.XP.LT.XL.AND.XP.GT.0.0) TA(I)=TA(I)-DAL2(I)   44700000
               1-DAR2(I)                                                          44800000
005211          IF(XS(I).GT.0.0.AND.XP.LT.0.0.AND.TE.LT.TD) TA(I)=TA(I)-DAR2(I)   44900000
005233          IF(XS(I).GT.0.0.AND.XP.LT.0.0.AND.TE.GT.TD) TA(I)=TA(I)-DAR2(I)   45000000
               1-RA(I)                                                            45100000
005260          IF(XS(I).EQ.0.0.AND.XP.GT.XL.AND.TB.GT.TC) TA(I)=TA(I)-DAL2(I)    45200000
005303          IF(XS(I).EQ.0.0.AND.XP.LT.XL.AND.XP.GT.0.0) TA(I)=TA(I)-DAL2(I)   45300000
               1-DAR2(I)                                                          45400000
005330          IF(XS(I).EQ.0.0.AND.XP.LT.0.0) TA(I)=TA(I)-RA(I)-DAR2(I)          45500000
005350          IF(XS(I).LT.0.0.AND.XP.GT.XL.AND.TB.GT.TC.AND.TE.LT.TD) TA(I)=     45600000
               1TA(I)-DAL2(I)                                                     45700000
005402          IF(XS(I).LT.0.0.AND.XP.GT.XL.AND.TB.GT.TC.AND.TE.GT.TD) TA(I)=     45800000
               1TA(I)-RA(I)-DAL2(I)                                               45900000
005437          IF(XS(I).LT.0.0.AND.XP.LT.XL.AND.XP.GT.0.0.AND.TE.LT.TD) TA(I)=    46000000
               1TA(I)-DAL2(I)-DAR2(I)                                             46100000
005471          IF(XS(I).LT.0.0.AND.XP.LT.XL.AND.XP.GT.0.0.AND.TE.GT.TD) TA(I)=    46200000
               1TA(I)-RA(I)-DAL2(I)-DAR2(I)                                       46300000
005526          IF(XS(I).LT.0.0.AND.XP.LT.0.0) TA(I)=TA(I)-RA(I)-DAR2(I)+DAL(I)   46400000
005551          SAS(I)=TA(I)-GA(I)                                                46500000
005560     4444 CONTINUE                                                          46600000
005560          NN=(N-1)/2                                                        46700000
005562          II=I-NN                                                           46800000
005564          IF(I.EQ.N) GO TO 11                                               46900000
005566          XS(I+1)=XS(1)-FLOAT(I)*D(I)*COS(THI)                              47000000
005575          IF(I.GT.NN) XS(I+1)=XS(1)+FLOAT(II)*D(I)*COS(THI)                 47100000
005606          YS(I+1)=YS(1)-FLOAT(I)*D(I)*SIN(THI)                              47200000
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                  IF(I.GT.NNN) YS(I+1)=YS(1)+FLOAT(I1)*D(1)*SIN(TH1)                    47300000
005626            M=I+1                                                                 47400000
005633            RO(M)=SQRT((XP-XS(M))*(XP-XS(M))+(YP-YS(M))*(YP-YS(M)))/XLAMDA        47500000
005644            OB(M)=    FA(D(I)*FLOAT(I),RO(1)*XLAMDA,RO(M)*XLAMDA)+OB(1)          47600000
005655            IF(I.GT.NN) OB(M)=OB(1)-FA(FLOAT(I-NN)*D(I),RO(1)*XLAMDA,           47700000
                 1RO(M)*XLAMDA)                                                       47800000
005672            IF(OB(1).GT.PI02  ) OB(M)=OB(1)-FA(D(I)*FLOAT(I),RO(1)*XLAMDA,      47900000
                 1RO(M)*XLAMDA)                                                       48000000
005707            IF(OB(1).GT.PI02  .AND.I.GT.NN)                                     48100000
                 1OB(M)=OB(1)+FA(FLOAT(I-NN)*D(I),RO(1)*XLAMDA,RO(M)*XLAMDA)         48200000
005734            IF(I.GT.NNN) GO TO 11                                               48300000
005740            I=I+1                                                               48400000
005741            GO TO 20                                                            48500000
005741         11 CONTINUE                                                            48600000
005741            SATAL=CMPLX(0.0,0.0)                                                48700000
005744            RATAL=CMPLX(0.0,0.0)                                                48800000
005746            TOTAL=CMPLX(0.0,0.0)                                                48900000
005751            DO  3 K=1,N                                                         49000000
005752            RATAL=RATAL+GGA(K)                                                  49100000
005760            SATAL=SATAL+SAS(K)                                                  49200000
005766          3 TOTAL=TOTAL+TA(K)                                                   49300000
005776            ATAL=CABS(TOTAL)                                                    49400000
006000            DBTAL=20.0*ALOG10(ATAL)                                             49500000
006003            GAM=CABS(RATAL)                                                     49600000
006005            DBGA=20.0*ALOG10(GAM)                                               49700000
006010            SASM=CABS(SATAL)                                                    49800000
006012            DBSAS=20.0*ALOG10(SASM)                                             49900000
006015            WR=REAL(TOTAL)                                                      50000000
006017            WI=AIMAG(TOTAL)                                                     50100000
006020            PHASE=ATAN2(WI,WR)                                                  50200000
006023            THS = THS*TTDEG                                                     50300000
006025            PHASE=PHASE*TTDEG                                                   50400000
006027            WRITE(6,4)  THS,ATAL,DBTAL,DBGA,DBSAS,PHASE                         50500000
006046          4 FORMAT(5X,*THS=*,F7.2,5X,*ATAL=*,E12.4,5X,*DBTAL=*,E12.4,5X,      50600000
                 1*DBGA=*,F12.4,5X,*DBSAS=*,E12.4,5X*PHASE=*E12.4)                    50700000
                *                                                                    50800000
                C L-1 STORES THE COMPUTED POINTS IN REVERSE ORDER IN THE ARRAY, THAT IS,  50900000
                C       THS FROM -179 TO +179 DEG FOR CARTESIAN PLOTTING             51000000
                C                                                                    51100000
                *                                                                    51200000
006046          5 L=L-1                                                             51300000
006050            THSTFD(L)=THS                                                     51400000
006052            AMPTFD(L)=ATAL                                                    51500000
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006053          DBTFD(L)=DBTAL                                                  51600000
CC6055          PHTFD(L)=PHASE                                                  51700000
006056          GO TO 9998                                                      51800000
      *                                                                         51900000
006057        1 CONTINUE                                                        52000000
      C     FIND MAX AMPTFD                                                   52100000
006057          AMAX=AMPTFD(1)                                                  52200000
CC6060          TMAX=THSTFD(1)                                                  52300000
CC6062          DO 6956 J=2,180                                                 52400000
CC6064          IF (AMPTFD(J).EQ.0.)  AMPTFD(J)=(AMPTFD(J-1)+AMPTFD(J+1))/2.    52500000
006070          IF (AMPTFD(J).LE.AMAX) GO TO 6956                               52600000
006073          AMAX=AMPTFD(J)                                                  52700000
CC6074          TMAX=THSTFD(J)                                                  52800000
006076       6956 CONTINUE                                                      52900000
      *                                                                         53000000
      C     NORMALIZE AMPTFD                                                  53100000
CC6100          DO 6957 J=1,180                                                 53200000
006102          AMPTFD(J)=AMPTFD(J)/AMAX                                        53300000
CC6104       6957 CONTINUE                                                      53400000
006106          PRINT 5553,AMAX,TMAX                                            53500000
CC6115       5553 FORMAT(//* MAX AMPTFD=*F9.5* FOR THSTFD=*F3* DEG*)            53600000
      *                                                                         53700000
CC6115          PRINT 29,(THSTFD(J),AMPTFD(J),DBTFD(J),PHTFD(J), J=1,180)       53800000
006135         29 FORMAT(///2X*THS*5X*AMPTFDNOR*7X*DBTFD*8X*PHASE*/(F5.3(4XF10.5)))  53900000
      *                                                                         54000000
006135          THSTFD(181)=-180.                                               54100000
006136          THSTFD(192)=30.                                                 54200000
006140          AMPTFD(181)=0.                                                  54300000
CC6140          AMPTFD(182)=.1                                                  54400000
006142          PHTFD(181)=-180.                                                54500000
006142          PHTFD(182)=30.                                                  54600000
006144          CALL PLTTFD(THSTFD,PHTFD,180)                                   54700000
CC6146          CALL PLTTFD(THSTFD,AMPTFD,180)                                  54800000
      *                                                                         54900000
      *                                                                         55000000
      *                                                                         55100000
      C  REORDER THSTFD VS DBTFD IN THE ARRAY,FROM 1 TO 359 DEG,FOR POLAR PLOT  55200000
      *                                                                         55300000
006151          KK=90                                                           55400000
006152          DO 1113 J=1,90                                                  55500000
006154          KK=KK+1                                                         55600000
006156          TEMP=THSTFD(KK)                                                 55700000
006157          THSTFD(KK)=THSTFD(J)+360                                        55800000
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006162          THSTFD(J)=TEMP                                                  55900000
006164          TEMP=DBTFD(KK)                                                  56000000
006165          DBTFD(KK)=DBTFD(J)                                              56100000
006167          DBTFD(J)=TEMP                                                   56200000
006170       1113 CONTINUE                                                      56300000
             **   IN LSCSBOX                                                    56400000
             *                                                                  56500000
006172          FIELD=5HTOTAL                                                   56600000
006173          DMAX=DBTFD(1)                                                   56700000
006174          TMAX=THSTFD(1)                                                  56800000
006176          DO 6958 J=2,180                                                 56900000
006200          IF (DBTFD(J).EQ.0.) DBTFD(J)=(DBTFD(J-1)+DBTFD(J+1))/2.         57000000
006204          IF(DBTFD(J).LE.DMAX) GO TO 6958                                 57100000
006207          DMAX=DBTFD(J)                                                   57200000
006210          TMAX=THSTFD(J)                                                  57300000
006212       6958 CONTINUE                                                      57400000
             *                                                                  57500000
             C   NORMALIZE DBTFD                                               57600000
006214          DO 6959 J=1,180                                                 57700000
006216          DBTFD(J)=DBTFD(J)-DMAX                                          57800000
006220          IF(DBTFD(J).LT.-40.) DBTFD(J)=-40.                              57900000
006224       6959 CONTINUE                                                      58000000
006226          PRINT 5554,DMAX,TMAX                                            58100000
006236       5554 FORMAT(///* MAX DBTFD=*F9.5* FOR THSTFD=*F3* DEG*)            58200000
006236          PRINT 5555,(THSTFD(J),DBTFD(J),J=1,180)                         58300000
006252       5555 FORMAT(//* THSTFD*7X*DBTFDNOR*/(2XF3,8XF10.5))                58400000
             *                                                                  58500000
006252          CALL POLPLT(THSTFD,DBTFD,180,7.5,8,1,N,TYPE,AL,XLAMDA,X,XL,H,RI,RS 58600000
                1,THI,DMAX,FIELD,SOURCE)                                        58700000
006275          PRINT 8888                                                      58800000
006301       8888 FORMAT(///)                                                   58900000
             *                                                                  59000000
006301          CALL TEST(N,AL,RS+RI,A,TYPE,SOURCE)                             59100000
006307          GO TO 6789                                                      59200000
006310       1112 CONTINUE                                                      59300000
006310          CALL CALPLT(0.,0.,999)                                          59400000
006313          STOP                                                            59500000
006315          END                                                             59600000
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                SUBROUTINE DFRCF(D,XN,Y,B,XLMDA)                                59700000
C                                                                               59800000
C       THIS ROUTINE IS TO COMPUTE THE DIFFRACTION COEFFICIENT                  59900000
C                                                                               60000000
000010          COMPLEX F1J,F2J,G,R,T1,D1,T2,D2,D,F1,F2,S                       60100000
C                                                                               60200000
000010          COMMON/PICONST/PI,TWOPI,STP,SQRTPI,TT,TTDEG,PI02,PI04           60300000
*                                                                               60400000
000010          BR=B*TT                                                         60500000
000011          ARG1=(PI+BR)/(2.0*XN)                                           60600000
000015          ARG2=(PI-BR)/(2.0*XN)                                           60700000
000020          CX1=COS(ARG1)                                                   60800000
000022          CX2=COS(ARG2)                                                   60900000
000024          SX1=SIN(ARG1)                                                   61000000
000026          SX2=SIN(ARG2)                                                   61100000
000030          X1=(BR+PI)/(2.0*XN*PI)                                          61200000
000037          N1=X1                                                           61300000
000041          E1=X1-N1                                                        61400000
000043          IF(E1.GT.0.5) N1=N1+1                                           61500000
000050          IF(E1.LT.-0.5) N1=N1-1                                          61600000
000054          FN1=FLOAT(N1)                                                   61700000
000055          X2=(BR-PI)/(2.0*XN*PI)                                          61800000
000061          N2=X2                                                           61900000
000063          E2=X2-N2                                                        62000000
000065          IF(E2.GT.0.5) N2=N2+1                                           62100000
000072          IF(E2.LT.-0.5) N2=N2-1                                          62200000
000076          FN2=FLOAT(N2)                                                   62300000
000077          A1=1.0+COS(-BR+2.0*XN*PI*FN1)                                   62400000
000113          A2=1.0+COS(-BR+2.0*XN*PI*FN2)                                   62500000
000127          SA1=SQRT(A1)                                                    62600000
000131          SA2=SQRT(A2)                                                    62700000
000133          XX=(SQRT( TWOPI*Y))*SA1                                         62800000
000146          YY=(SQRT( TWOPI*Y))*SA2                                         62900000
000156          XXS=XX*XX                                                       63000000
000160          YYS=YY*YY                                                       63100000
000161          PQ=SQRT(PI02)                                                   63200000
000164          CALL CS(C1,S1,XXS)                                              63300000
000166          CC1=0.5-C1                                                      63400000
000170          SS1=0.5-S1                                                      63500000
000172          F1J= PQ*CMPLX(SS1,CC1)                                          63600000
000202          CALL CS(C2,S2,YYS)                                              63700000
000205          CC2=0.5-C2                                                      63800000
```

```
000207          SS2=0.5-S2                                                      63900000
000211          F2J= PQ*CMPLX(SS2,CC2)                                          64000000
000221          P=-PI04                                                         64100000
000222          Q=CMPLX(0.0,P)                                                  64200000
000225          R=CEXP(Q)                                                       64300000
000227          S=(-0.25*R*SQRT(XLMDA))/(PI*XN)                                 64400000
000254          T1=S*2.0*CEXP(CMPLX(0.0,XXS))                                   64500000
000270          D1=T1*F1J*CX1*(XX/SX1)                                          64600000
000302          T2=S*2.0*CEXP(CMPLX(0.0,YYS))                                   64700000
000316          D2=T2*F2J*CX2*(YY/SX2)                                          64800000
000330          D= D1+D2                                                        64900000
000340          RETURN                                                          65000000
000341          END                                                             65100000

                SUBROUTINE KKDC(D,XN,XL,PHIP,PHI,XLMDA,T)                       65200000
C               C     - KARP - KELLER DIFFRACTION COEFFICIENT                   65300000
C               XL    - DISTANCE PARAMETER IN ANY UNIT                          65400000
C               XLMDA - WAVELENGTH IN THE SAME UNIT                             65500000
C               PHIP  - ANGLE OF INCIDENCE IN DEGREES                           65600000
C               PHI   - ANGLE OF OBSERVATION IN DEGREES                         65700000
C               XN    - WEDGE ANGLE = (2.-XN)*PI                                65800000
C               T     - D/D(PHIP) OR D/D(PHI) = 1 OR 0                          65900000
000012          INTEGER T                                                       66000000
000012          COMPLEX D,D1,D2                                                 66100000
000012          BETAP=PHI+PHIP                                                  66200000
000013          BETAM=PHI-PHIP                                                  66300000
000015          CALL CD(D1,XN,XL,BETAP,XLMDA, 1  ,T)                            66400000
000022          CALL CD(D2,XN,XL,BETAM,XLMDA,-1  ,T)                            66500000
000033          D=D2-D1                                                         66600000
000043          RETURN                                                          66700000
000044          END                                                             66800000
```

```
                      SUBROUTINE CD(D,XN,XL,BETA,XLMDA,T1,T2)                                  66900000
                C     T1  - BETP OR BETM 1 OR -1                                               67000000
                C     T2  - D/D(PHIS) OR D/D(PHIO) 1 OR 0                                      67100000
000012                INTEGER T1,T2                                                            67200000
000012                COMPLEX D,CP,CM,DP,DM,V,P,CCP,CCM,C,F1,F2                                67300000
000012                P(X)=CEXP(CMPLX(.0,X))                                                   67400000
                C                                                                              67500000
000030                COMMON/PICONST/PI,TWOPI,STP,SQRTPI,TT,TTDEG,PIO2,PIO4                    67600000
                *                                                                              67700000
000030                XK=TWOPI/XLMDA                                                           67800000
000031                C=P(-PIO4 )/(4.*(XN**2)*SQRT(TWOPI*XK))                                  67900000
000053                BR=BETA*TT                                                               68000000
000054                TP=(PI+BR)/(2.*XN)                                                       68100000
000060                ATP=ABS(TP)                                                              68200000
000062                IF(ATP .LT. 0.01)GO TO 10                                                68300000
000065                XNP=(BR+PI)/(2.*XN*PI)                                                   68400000
000070                NP=XNP                                                                   68500000
000072                E1=XNP-NP                                                                68600000
000074                IF(E1. GT.  0.5)NP=NP+1                                                  68700000
000100                IF(E1 .LT. -0.5)NP=NP-1                                                  68800000
000104                AP=1.+COS(-BR+2.*XN*NP*PI)                                               68900000
000120                XKAP=XK*XL*AP                                                            69000000
000122                CP=CEXP(CMPLX(.0,-PIO4 ))/(4.*(XN**2)*SQRT(TWOPI*XK)*(SIN((PI+BR)/      69100000
                     1(2.*XN))**2))                                                           69200000
000155                CCP=CP*V(XKAP)                                                           69300000
000175                GO TO 11                                                                 69400000
000201          10    A1=2.*XK*XL*(XN**2)*(ATP**2)                                             69500000
000207                CALL CS(C1,S1,A1)                                                        69600000
000211                F1=CMPLX(.0,4.*XK*XL*(XN**2))+2.*SQRTPI  *P(A1)*((2.*XK*XL*(XN**2)       69700000
                     1)**1.5)*ATP*(P(-PIO4 )-SQRT(2.)*CMPLX(C1,-S1))                          69800000
000273                CCP=C*F1                                                                 69900000
000301          11    TM=(PI-BR)/(2.*XN)                                                       70000000
000304                ATM=ABS(TM)                                                              70100000
000306                IF(ATM .LT. 0.01)GO TO 20                                                70200000
000311                XNM=(BR-PI)/(2.*XN*PI)                                                   70300000
000314                NM=XNM                                                                   70400000
000316                E2=XNM-NM                                                                70500000
000320                IF(E2 .GT.  0.5)NM=NM+1                                                  70600000
000324                IF(E2 .LT. -0.5)NM=NM-1                                                  70700000
000330                AM=1.+COS(-BR+2.*XN*NM*PI)                                               70800000
000344                XKAM=XK*XL*AM                                                            70900000
000346                CM=CEXP(CMPLX(.0,-PIO4 ))/(4.*(XN**2)*SQRT(TWOPI*XK)*(SIN((PI-BR)/      71000000
```

```
     1(2.*XN))**2))                                                                    71100000
000411        CCM=CM*V(XKAM)                                                           71200000
000421        GO TO 21                                                                 71300000
000425   20   AL=2.*XK*XL*(XN**2)*(ATP**2)                                             71400000
000433        CALL CS(C1,S1,AL)                                                        71500000
000435        F2=CMPLX(.0,4.*XK*XL*(XN**2))+2.*SQRTPI  *P(AL)*((2.*XK*XL*(XN**2)       71600000
     1)**1.5)*ATM*(P(-PI04 )-SQRT(2.)*CMPLX(C1,-S1))                                  71700000
000517        CCM=C*F2                                                                 71800000
000525   21   IF(T1 .EQ.  1  )GO TO 1                                                  71900000
000527        DP=CCP                                                                   72000000
000531        DM=-CCM                                                                  72100000
000534        IF(T2 .EQ.  1  )DP=-CCP                                                  72200000
000540        IF(T2 .EQ.  1  )DM=CCM                                                   72300000
000545        GO TO 2                                                                  72400000
000546   1    DP=CCP                                                                   72500000
000551        DM=-CCM                                                                  72600000
000553   2    U=DP+DM                                                                  72700000
000560        RETURN                                                                   72800000
000561        END                                                                      72900000

              COMPLEX FUNCTION V(X)                                                    73000000
        C     TRANSITION FUNCTION FOR THE INTEGRAL WITH THE INTEGRAND HAVING THE       73100000
        C     POLE OF ORDER TWO CLOSE TO THE SADDLE                                    73200000
        C     X = K*A(BETA)                                                            73300000
000003        COMPLEX P                                                                73400000
000003        P(X)=CEXP(CMPLX(.0,X))                                                   73500000
        C                                                                              73600000
000016        COMMON/PICONST/PI,   TP,STP,SQRTPI,TT,TTDEG,PI02,PI04                    73700000
000016        CALL CS(C,S,X)                                                           73800000
000021        V=CMPLX(.0,2.*X)+2.*(X**1.5)*P(X)*SQRTPI  *(P(-PI04 )-SQRT(2.)*          73900000
     1CMPLX(C,-S))                                                                    74000000
000071        RETURN                                                                   74100000
000073        END                                                                      74200000
```

```
                      SUBROUTINE WANG(PH,PHP,XN,XL,D1,D2)                                74300000
000011                COMPLEX  D1,D2,DA,DB,DH,DS,U,V                                     74400000
000011                DH(U,V)=SQRT(6.283185301796)*(U+V)                                 74500000
000036                DS(U,V)=SQRT(6.283185301796)*(U-V)                                 74600000
000062                CALL DFRCF(DA,XN,XL,PH-PHP,1.0)                                    74700000
000067                CALL DFRCF(DB,XN,XL,PH+PHP,1.0)                                    74800000
000077                D1=DH(DA,DB)                                                       74900000
000111                D2=DS(DA,DB)                                                       75000000
000120                RETURN                                                             75100000
000121                END                                                                75200000

                      SUBROUTINE CS(C,S,X)                                               75300000
                C                                                                        75400000
                C          COMPUTES THE FRESNEL INTEGRALS                                75500000
                C                                                                        75600000
                C       DESCRIPTION OF PARAMETERS                                        75700000
                C          C       THE RESULTANT VALUE C(X)                              75800000
                C          S       THE RESULTANT VALUE S(X)                              75900000
                C          X       THE ARGUMENT OF FRESNEL INTEGRALS                     76000000
                C                  IF X IS NEGATIVE, THE ABSOLUTE VALUE IS USED          76100000
                C                                                                        76200000
                C          THE ARGUMENT VALUE X REMAINS UNCHANGED                        76300000
                C                                                                        76400000
                C          C(X)=INTEGRAL(COS(T)/SQRT(2*LI*T) SUMMED OVER T FROM 0 TO X)  76500000
                C          S(X)=INTEGRAL(SIN(T)/SQRT(I*LI*T) SUMMED OVER T FROM 0 TO X)  76600000
                C                                                                        76700000
                C          EVALUATION                                                    76800000
                C          USING DIFFERENT APPROXIMATIONS FOR X .LT. 4 AND X .GT. 4      76900000
                C                                                                        77000000
                C          REFERENCE                                                     77100000
                C           COMPUTATION OF FRESNEL INTEGRALS  BY BOERSMA,                77200000
                C          MATHEMATICAL TABLES AND OTHER AIDS TO COMPUTATION, VOL. 14,    77300000
                C          1960, NO. 72, P. 380                                          77400000
                C                                                                        77500000
0006                  Z=ABS(X)                                                           77600000
0007                  IF(Z-4.)1,1,2                                                      77700000
0012                1 C=SQRT(Z)                                                          77800000
0016                  S=Z*C                                                              77900000
0020                  Z=(4.-Z)*(4.+Z)                                                    78000000
0024                  C=C*((((((5.100785E-11*Z+5.244297E-9)*Z+5.451182E-7)*Z            78100000
                     1+3.273308E-5)*Z+1.C20418E-3)*Z+1.102544E-2)*Z+1.840965E-1)        78200000
0037                  S=S*((((((6.677681E-10*Z+5.883158E-8)*Z+5.051141E-6)*Z            78300000
                     1+2.441816E-4)*Z+6.121320E-3)*Z+8.026490E-2)                       78400000
```

```
0050          RETURN                                                                    78300000
0051        2 D=COS(Z)                                                                  78500000
0053          S=SIN(Z)                                                                  78700000
0061          Z=4./Z                                                                    78800000
0063          A=((((((( 8.768258E-4*Z-4.169289E-3)*Z+7.970943E-3)*Z-6.792801E-3)      78900000
             1*Z-3.095341E-4)*Z+5.972151E-3)*Z-1.606428E-5)*Z-2.493322E-2)*Z           79000000
             2-4.444091E-9                                                            79100000
0100          B=((((((-6.633926E-4*Z+3.401409E-3)*Z-7.271690E-3)*Z+7.428246E-3)       79200000
             1*Z-4.027145E-4)*Z-9.314910E-3)*Z-1.207998E-6)*Z+1.994711E-1             79300000
0113          Z=SQRT(Z)                                                                79400000
000115        C=0.5+Z*(D*A+S*B)                                                        79500000
000125        S=0.5+Z*(S*A-D*B)                                                        79600000
000132        RETURN                                                                   79700000
000133        END                                                                      79800000
```

```
                      SUBROUTINE TEST(N,AL,XS,A,TYPE)                                   79900000
                    C THIS SUBROUTINE PROGRAM COMPUTES THE RADIATION FIELD OF HORN ANTENNA 80000000
                    C                                                                   80100000
000010                DIMENSION X(180),AM(180),AP(180),DG(180),A(180),ANG(180)          80200000
000010                DIMENSION THIFD(185),AMPIFD(185),DBIFD(185)                       80300000
000010                COMPLEX F,A,DG,CDG,TAL                                            80400000
000010                COMMON XLAMDA,XPIN,XL,H,RI,RS,THI,DMAX,FIELD,SOURCE               80500000
000010                COMMON/PICONST/PI,   TP,STP,SQRTPI,TT,TTDEG,PIO2,PIO4             80600000
                    C       XPIN IS POINT OF INCIDENCE WHICH IS X IN MAIN PROGRAM      80700000
                    C                                                                   80800000
000010                F(Z)=CEXP( CMPLX(0.,-6.2831853071796*Z))/SQRT(6.2831853071796*Z)  80900000
000036                FA(SA,SB,SC)= ACOS((SB*SB+SC*SC-SA*SA)/(2.0*SB*SC))              81000000
000057                FC(AA,SB,SC)=SQRT(SB*SB+SC*SC-2.0*SB*SC*COS(AA))                  81100000
000101                FB(SX)=ABS(COS(SX/2.0))**2.0                                      81200000
                    C                                                                   81300000
                    C FB(SX) IS THE OBLIQUITY FACTOR.    TO IGNORE IT, SET FB(SX)=1.   81400000
                    C                                                                   81500000
                    *                                                                   81600000
000120                NN=(N+1)/2                                                        81700000
000122                L=0                                                               81800000
000123                D=0.0                                                             81900000
000123                IF(N.GT.1) D=AL/FLOAT(N-1)                                        82000000
000130                TH=0.0                                                            82100000
000131              2 CONTINUE                                                          82200000
000131                IF(TH.EQ.90.0) GO TO 15                                           82300000
000133                THR=TH*TT                                                         82400000
000134                ANG(1)=THR                                                        82500000
000136                X(1)=XS                                                           82600000
000137                DG(1)=A(1)*F(XS)*FB(THR)                                          82700000
000153                IF(TYPE.EQ.3.0.AND.THR.LT.PIO2  ) DG(1)=DG(1)*COS(THR)            82800000
000175                IF(TYPE.EQ.3.0.AND.THR.GT.PIO2  ) DG(1)=DG(1)*COS(PI-THR)         82900000
000221                IF(N.EQ.1) GO TO 11                                               83000000
000223                I=2                                                               83100000
000224              3 CONTINUE                                                          83200000
000224                X(I)=FC(PI*0.5+THR,FLOAT(I-1)*D,XS)                               83300000
000236                IF(I.GT.NN) X(I)=FC(PIO2  -THR,FLOAT(I-NN)*D,XS)                  83400000
000251                IF(TH.GT.90.0) X(I)=FC(1.5*PI-THR,FLOAT(I-1)*D,XS)                83500000
000266                IF(TH.GT.90..AND.I.GT.NN) X(I)=FC(THR-PIO2  ,FLOAT(I-NN)*D,XS)    83600000
000311                ANG(I)=THR+FA(FLOAT(I-1)*D,XS,X(I) )                              83700000
000323                IF(I.GT.NN) ANG(I)=THR-FA(FLOAT(I-NN)*D,XS,X(I) )                 83800000
000336                IF(TH.GT.90.0) ANG(I)=THR-FA(FLOAT(I-1)*D,XS,X(I) )               83900000
000352                IF(TH.GT.90.0.AND.I.GT.NN) ANG(I)=THR+FA(FLOAT(I-NN)*D,XS,X(I) )  84000000
```

```
000376          DG(I)=A(I)*F(X(I))*FB(ANG(I) )                                  84100000
000416          IF(TYPE.EQ.3.0.AND.ANG(I).LT.PI02  ) DG(I)=DG(I)*COS(ANG(I))    84200000
000442          IF(TYPE.EQ.3.0.AND.ANG(I).GT.PI02  ) DG(I)=DG(I)*COS(PI-ANG(I)) 84300000
000470          IF(I.EQ.N) GO TO 11                                             84400000
000472          I=I+1                                                           84500000
000473          GO TO 3                                                         84600000
000474       11 CONTINUE                                                        84700000
000474          TAL=CMPLX(0.0,0.0)                                              84800000
000477          DO 33 K=1,N                                                     84900000
000500          CDG=DG(K)                                                       85000000
000503          ANGL=ANG(K)*TTDEG                                               85100000
000505          ADG=CABS(CDG)                                                   85200000
000507          TAL=TAL+DG(K)                                                   85300000
000516       33 CONTINUE                                                        85400000
000523          ATAL=CABS(TAL)                                                  85500000
000524          IF(TH.EQ.0.0) XNOM=ATAL                                         85600000
000532          DBTAL=20.0*ALOG10(ATAL)                                         85700000
000536          WRITE(6,4) TH,ATAL,DBTAL                                        85800000
000547        4 FORMAT(    5X*TH=*F10.4,5X,*MAGNITUDE= *,E15.4,5X,*DBHA= *,E15.4) 85900000
000547          L=L+1                                                           86000000
              *                                                               86100000
000551          THIFD(L)=TH                                                     86200000
000553          AMPIFD(L)=ATAL                                                  86300000
000554          DBIFD(L)=DBTAL                                                  86400000
000556       15 CONTINUE                                                        86500000
000556          TH=TH+2.0                                                       86600000
000560          IF(TH.LE.360.0) GO TO 2                                         86700000
000566          PRINT 39,(THIFD(J),AMPIFD(J),DBIFD(J), J=1,L)                   86800000
000604       39 FORMAT(///2X* TH*7X*AMPLITUDE*7X* DBHA*/(F5,2(5XF10.5)))        86900000
            C    FIND MAX AMPIFD                                              87000000
000604          AMAX=AMPIFD(1)                                                  87100000
000605          TMAX= THIFD(1)                                                  87200000
000607          DO 6596 J=2,L                                                   87300000
000614          IF (AMPIFD(J).LE.AMAX) GO TO 6596                               87400000
000617          AMAX=AMPIFD(J)                                                  87500000
000620          TMAX= THIFD(J)                                                  87600000
000621    6596 CONTINUE                                                         87700000
            C    NORMALIZE AMPIFD                                             87800000
000624          DO 6597 J=1,L                                                   87900000
000625          AMPIFD(J)=AMPIFD(J)/AMAX                                        88000000
000627    6597 CONTINUE                                                         88100000
000631          PRINT 5555,AMAX,TMAX                                            88200000
000641     5555 FORMAT(//* MAX AMPIFD=*F9.5,* FOR THIFD=*F3* DEG*)              88300000
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```
      **    IN TEST                                                          88400000
      *                                                                      88500000
00641         FIELD=5HINCID                                                 88600000
00642         DMAX=DBIFD(1)                                                 88700000
00644         TMAX=THIFD(1)                                                 88800000
00646         DO 6598 J=2,L                                                 88900000
00652         IF(DBIFD(J).LE.DMAX) GO TO 6598                               89000000
00655         DMAX=DBIFD(J)                                                 89100000
00656         TMAX=THIFD(J)                                                 89200000
00657    6598 CONTINUE                                                      89300000
           C   NORMALIZE DBFA WHICH IS DBIFD                               89400000
00662         DO 6599 J=1,L                                                 89500000
00663         DBIFD(J)=DBIFD(J)-DMAX                                        89600000
00665         IF(DBIFD(J).LT.-40.) DBIFD(J)=-40.                            89700000
00671    6599 CONTINUE                                                      89800000
00674         PRINT 5556,DMAX,TMAX                                          89900000
00703    5556 FORMAT(///* MAX DBIFD=*F9.5* FOR THIFD=*F3* DEG*)             90000000
00703         PRINT 40,(THIFD(J),AMPIFD(J),DBIFD(J), J=1,L)                 90100000
00722      40 FORMAT(//* THIFD*5X*AMPIFDNOR*7X*DBIFDNOR*/(F5,2(4XF10.5)))   90200000
00722         CALL POLPLT(THIFD,DBIFD, 180,7.5,8,1,N,TYPE,AL,XLAMDA,XPIN,XL,H,RI 90300000
              1,RS,THI,DMAX,FIELD,SOURCE)                                   90400000
           ***                                                              90500000
00751         THIFD(L+1)=0.                                                 90600000
00753         THIFD(L+2)=30.                                                90700000
00754         AMPIFD(L+1)=0.                                                90800000
00755         AMPIFD(L+2)=.1                                                90900000
00757         CALL PLTIFD(THIFD,AMPIFD,180)                                 91000000
00761         RETURN                                                        91100000
00762         END                                                           91200000


              SUBROUTINE PLTIFD(THSTFD,AMPTFD,NPTS)                         91300000
000006        DIMENSION THSTFD(1),AMPTFD(1)                                 91400000
000006        TMAJ=1.                                                       91500000
000007        TMIN=3.                                                       91600000
000011        CALL NOTATE(0.00,0.2,.28,11HTOTAL FIELD,0.,11)                91700000
000015        CALL CALPLT(0.,1.0,-3)                                        91800000
000020        CALL AXES(0.,0.,90.,10.,0.,0.1,1.,5.,9HAMPLITUDE,.28,9)       91900000
000033        CALL AXES(0.,0.,0.,12.,-180.,30.,TMAJ,TMIN,10HTHSTFD),DEG,.28,-10) 92000000
000046        CALL AXES(0.,10.,0.,12.,   0.,30.,TMAJ,TMIN,1H ,0.,1)         92100000
000061        CALL AXES(12.,0.0,90.,10.,0.,0.1,1.,5.,1H ,0.,-1)             92200000
000074        CALL LINE(THSTFD,AMPTFD,NPTS,1,0,0,0.)                        92300000
000103        CALL NFRAME                                                   92400000
000104        RETURN                                                        92500000
000105        END                                                           92600000
```

```
      SUBROUTINE PLTTFDP(THSTFD,PHTFD,NPTS)                              92700000
      DIMENSION THSTFD(1),PHTFD(1)                                       92800000
      TMAJ=1.                                                            92900000
      TMIN=3.                                                            93000000
      CALL NOTATE(0.00,0.2,.28,11HTOTAL FIELD,0.,11)                     93100000
      CALL CALPLT(0.,1.0,-3)                                             93200000
      CALL AXES(0.,0.,90.,12.,-180.,30.,1.,3.,9HPHASE,DEG,.28,9)        93300000
      CALL AXES(0.,C.,0.,12.,-180.,30.,TMAJ,TMIN,10HTHSTFD,DEG,.28,-10) 93400000
      CALL AXES(0.,12.,0.,12.,-180.,30.,TMAJ,TMIN,1H ,0.,1)              93500000
      CALL AXES(12.,0.0,90.,12.,-180.,30.,1.,3.,1H ,0.,-1)               93600000
      CALL LINE(THSTFD,PHTFD,NPTS,1,0,0,0.)                              93700000
      CALL NFRAME                                                        93800000
      RETURN                                                             93900000
      END                                                                94000000
```

```
                SUBROUTINE PULPLT(DEGS,DBS,NPTS,DIAM,NOCIR,NPLOTS,N,TYPE,AL,      94100000
               1XLAMDA,X,XL,H,RI,RS,THI,DMAX,FIELD,SOURCE)                        94200000
      *                                                                           94300000
0026            DIMENSION DEGS(1),DBS(1),CHTAB(16)                              94400000
C026            DIMENSION ANUM(11),FIELD(2)                                     94500000
0026            DIMENSION COS(400),RHOX(400),RHOY(400),PHI(400)                 94600000
      *                                                                           94700000C
0026            RAD  =DIAM/2.0                                                  94800000
C027            HGT=.21                                                         94900000
      *                                                                           95000000
0031            CHTAB(1) =1H                                                    95100000
0032            CHTAB(2) =1H5                                                   95200000
0034            CHTAB(3) =2H10                                                  95300000
0035            CHTAB(4) =2H15                                                  95400000
C037            CHTAB(5) =2H20                                                  95500000
0040            CHTAB(6) =2H25                                                  95600000
0042            CHTAB(7) =2H30                                                  95700000
C043            CHTAB(8) =2H35                                                  95800000C
      *                                                                           95900000
      *                                                                           96000000
0045            CALL NOTATE (0.,0.,HGT,3,0.,-1)                                 96100000
0051            RADO =RAD                                                       96200000
0052            DELTR=RAD/NOCIR                                                 96300000
C060            CX=10.                                                          96400000C
C061            PX=10.                                                          96500000
0062            AY= 5.0                                                         96600000
C063            PY=5.                                                           96700000C
0064            K=1                                                             96800000
0065            HGT=.14                                                         96900000
      *                                                                           97000000
C067          1 CONTINUE                                                        97100000
0067            DO 5 I=1,NOCIR                                                  97200000
C071            RADF=RADO                                                       97300000
0073            CALL CIRCLE(CX ,AY,0.,360.,RADO,RADF,3)                         97400000
C101            IF(I.EQ.3)K=2                                                   97500000
C110            CALL NOTATE (CX,AY,HGT,CHTAB(I),270.,K)                         97600000
0116            RADO=RADO-DELTR                                                 97700000
0120            CX= CX-DELTR                                                    97800000
0121          5 CONTINUE                                                        97900000
      ***  CORDINATES FOR CENTER OF CIRCLE  ****                                98000000
0127            CNTRX=PX-RAD                                                    98100000
0130            CNTRY=PY                                                        98200000
```

```
000132          ANGLE=.174532925                                                98300000
000133          TIC=.1                                                          98400000
000135          RPT=RAD+TIC                                                     98500000
000136          DELTA=.174532925                                                98600000
                *                                                               98700000
                ***    DRAW TIC MARKS EVERY 10 DEGREES    ***                   98800000
                *                                                               98900000
000140          DO 50 I=1,36                                                    99000000
                ***    PAGE COORDINATES    ***                                  99100000
000141          TICX1=CNTRX+RAD*COS(ANGLE)                                      99200000
000145          TICY1=CNTRY+RAD*SIN(ANGLE)                                      99300000
000152          TICX2=CNTRX+RPT*COS(ANGLE)                                      99400000
000157          TICY2=CNTRY+RPT*SIN(ANGLE)                                      99500000
000164          CALL CALPLT(TICX1,TICY1,3)                                      99600000
000167          CALL CALPLT(TICX2,TICY2,2)                                      99700000
000172          ANGLE=ANGLE+DELTA                                               99800000
000174       50 CONTINUE                                                        99900000
                *                                                              100000000
                *** DRAW LABLES ***                                            100100000
                *                                                              100200000
000202          ANUM(1)=N                                                      100300000
000203          ANUM(2)=TYPE                                                   100400000
000205          ANUM(3)=AL                                                     100500000
000206          ANUM(4)=XLAMDA                                                 100600000
000210          ANUM(5)=X                                                      100700000
000211          ANUM(6)=XL                                                     100800000
000213          ANUM(7)=H                                                      100900000
000214          ANUM(8)=RI                                                     101000000
000216          ANUM(9)=RS                                                     101100000
000217          ANUM(10)=THI/(.1*DELTA)                                        101200000
000222          ANUM(11)=DMAX                                                  101300000
000224          CALL NOTATE(11.40,9.0,.21,14HTRANSMITED WL=,270.,14)           101400000
000230          CALL NUMBER(11.40,6.5,.21,ANUM(4),270.,-1)                     101500000
000236          CALL NOTATE(11.40,4.3,.21,12HINCID RANGE=,270.,12)             101600000
000242          CALL NUMBER(11.40,2.0,.21,ANUM(8),270.,2)                      101700000
000250          CALL NOTATE(11.10,9.0,.21,12HINCID POINT=,270.,12)             101800000
000254          CALL NUMBER(11.10,6.7,.21,ANUM(5),270., 2)                     101900000
000262          CALL NOTATE(11.10,4.3,.21,12HSCATER RNGE=,270.,12)             102000000
000266          CALL NUMBER(11.10,2.0,.21,ANUM(9),270.,-1)                     102100000
000274          CALL NOTATE(10.80,9.0,.21,11HBOX LENGTH=,270.,11)              102200000
000300          CALL NUMBER(10.80,6.9,.21,ANUM(6),270.,2)                      102300000
000306          CALL NOTATE(10.80,4.3,.21,12HINCID ANGLE=,270.,12)             102400000
000312          CALL NUMBER(10.80,2.0,.21,ANUM(10),270.,-1)                    102500000
```

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000320          CALL NOTATE(10.50,9.0,.21,11HBOX HEIGHT=,270.,11)                    102600000
000324          CALL NUMBER(10.50,6.9,.21,ANUM(7),270.,-1)                           102700000
000332          CALL NOTATE(10.50,4.3,.21,12HNORMALIZ D3=,270.,12)                   102800000
000336          CALL NUMBER(10.50,2.0,.21,ANUM(11),270.,3)                           102900000
000344          CALL NOTATE( 1.70,4.3,.21,15HLINE SOURCES,N=,270.,15)                103000000
000350          CALL NUMBER( 1.70,1.6,.21,ANUM(1),270.,-1)                           103100000
000356          CALL NOTATE( 1.40,4.8,.21,20H          CURNT TYPE=,270.,20)          103200000
000362          CALL NUMBER( 1.40,1.2,.21,ANUM(2),270.,-1)                           103300000
000370          CALL NOTATE( 1.40,4.8,.21,SOURCE,270.,9)                             103400000
000375          CALL NOTATE(1.10,9.0,.21,11H      FIELD,270.,11)                     103500000
000401          CALL NOTATE(1.10,9.0,.21,FIELD,270.,5)                               103600000
000406          CALL NOTATE( 1.10,4.0,.21,12HAPERT WIDTH=,270.,12)                   103700000
000412          CALL NUMBER(1.10,1.75,.21,ANUM(3),270.,3)                            103800000
          *** DRAW X AXIS                                                            103900000
000420          AX=PX-DIAM-.5                                                        104000000
000427          CALL CALPLT(AX,AY,3)                                                 104100000
000431          AX=PX+.5                                                             104200000
000433          CALL CALPLT(AX,AY,2)                                                 104300000
          *** DRAW ZERO DEGREES AFTER HORIZONTAL                                    104400000
000436          HGT=.21                                                              104500000
000437          AX=PX                                                                104600000
000441          AY=AY-.05                                                            104700000
000443          CALL NOTATE (AX,AY,HGT,1H0,270.,1)                    DEGREES        104800000
000447          AX=AX+.21                                                            104900000
000451          AY=AY-.12                                                            105000000
          *** DEGREE SYMBOL                                                        105100000
000453          CALL NOTATE (AX,AY,.07,1HO,270.,1)                                   105200000
          ***DRAW Y AXIS                                                           105300000
000457          AY=5.0                                                               105400000
000460          AX= PX-RAD                                                           105500000
000462          AY= AY-RAD-.5                                                        105600000
000466          CALL CALPLT(AX,AY,3)                                                 105700000
000470          AY=AY+ DIAM+1.                                                       105800000
000476          CALL CALPLT(AX,AY,2)                                  VERTICAL       105900000
          ***DRAW 90 DEGS                                                          106000000
000501          AY=AY-.1                                                             106100000
000503          CALL NOTATE(AX,AY,HGT,2H90,270.,2)                                   106200000
000507          AX=AX+HGT                                                            106300000
000511          AY=AY-.32                                                            106400000
000513          CALL NOTATE (AX,AY,.07,1HO,270.,1)                                   106500000
          *** DRAW 180 DEGREES                                                     106600000
000517          AX=PX-DIAM-.3                                                        106700000
000525          AY=5.0                                                               106800000
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000527          CALL NOTATE (AX,AY,HGT,3H180,270.,3)                          106900000
000533          AX=AX+.21                                                     107000000
000535          AY=AY-.5                                                      107100000
000537          CALL NOTATE (AX,AY,.07,1HO,270.,1)                            107200000
                *                                                             107300000
                ***DRAW 270 DEGS                                              107400000
000543          AX=PX-RAD                                                     107500000
000545          AY=5.0-RAD-.05                                                107600000
000550          CALL NOTATE(AX,AY,HGT,3H270,270.,3)                           107700000
000554          AX=AX+HGT                                                     107800000
000556          AY=AY-.5                                                      107900000
000560          CALL NOTATE (AX,AY,.07,1HO,270.,1)                            108000000
                *                                                             108100000
                **                                                            108200000
                *                                                             108300000
000564        151 CONTINUE                                                    108400000
                *                                                             108500000
                *** PLOT POLAR CURVES ***                                      108600000
                *                                                             108700000
                *** SCALE DECIBELS AND CONVERT POLAR COORDINATES TO CART. COORDS.  108800000
000564          DO 500 JJ=1,NPTS                                              108900000
000571          PHI = DEGS(JJ)*.0174532925                                    109000000
000573          CDB(JJ)=DBS(JJ)+40.                                           109100000
000576          CDB(JJ)=.025*RAD*CDB(JJ)                                      109200000
000601          RHOX(JJ)=CDB(JJ)*COS(PHI      )+PX-RAD                        109300000
000610          RHOY(JJ)=CDB(JJ)*SIN(PHI      )+5.0                           109400000
000616        500 CONTINUE                                                    109500000
000624          LIM=NPTS-1                                                    109600000
                ***BEGIN PLOTTING WITH PEN UP***                              109700000
000625          IPEN=3                                                        109800000
000627          DO 100 I=1,LIM                                                109900000
000630          J=I+1                                                         110000000
000632          CALL CIRCLE(RHOX(I),RHOY(I),DEGS(I),DEGS(J),CDB(I),CDB(J),IPEN)  110100000
000655          IF(I.GT.1)GO TO 110                                           110200000
000664          IPEN=2                                                        110300000
000665        110 CONTINUE                                                    110400000
000665        100 CONTINUE                                                    110500000
                *                                                             110600000
000670          CALL NFRAME                                                   110700000
000671          RETURN                                                        110800000
000672          END                                                           110900000
```

```
                SUBROUTINE PLTIFD(THIFD,AMPIFD,NPTS)                                111000000
000006          DIMENSION THIFD(1),AMPIFD(1)                                        111100000
000016          TMAJ=1.                                                             111200000
000017          TMIN=3.                                                             111300000
000021          CALL ROTATE(0.00,0.2,.28,14HINCIDENT FIELD,0.,14)                   111400000
000035          CALL CALPLT(0.,1.0,-3)                                              111500000
000029          CALL AXES(0.,0.,90.,10.,0.,0.1,1.,5.,9HAMPLITUDE,.28,9)            111600000
000033          CALL AXES(0.,0.,0.,12.,0.,30.,TMAJ,TMIN,9HTHIFD,DEG,.28,-9)        111700000
000046          CALL AXES(0.,10.,0.,12.,-180.,30.,TMAJ,TMIN,1H ,0.,1)               111800000
000061          CALL AXES(12.,0.0,90.,10.,0.,0.1,1.,5.,1H ,0.,-1)                   111900000
000074          CALL LINE(THIFD,AMPIFD,180,1,0,0,0.)                                112000000
000104          CALL NFRAME                                                         112100000
000105          RETURN                                                              112200000
000106          END                                                                 112300000
```

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